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THE GEOLOGICAL SOCIETY OF LONDON.

PROCEEDINGS

OF

THE GEOLOGICAL SOCIETY.

DECEMBER 1, 1858.

The Rev. Dr. John Anderson, Newburgh, Fife, J. D. Smithe, Esq., Madhopoor, Punjâb, Samuel Laing, Esq., Hordle House, Lymington, Hants, James Clarke, Esq., Westcott, Dorking, Walter Baldock Durrant Mantell, Esq., New Zealand, George Dixon, Esq., C.E., Whitehaven, John Augustus Tulk, Esq., Whitehaven, Major-General Emmett, R.E., Henry T. Plews, Esq., Bedale, Yorkshire, The Right Hon. Lord Kinnaird, Rossie Priory, Scotland, and Grosvenor Square, London, and Capt. H. H. Godwin-Austen, H.M. 24th Regiment, were elected Fellows.

The following communication was read:—

On the SUCCESSION *of the* OLDER ROCKS *in the* NORTHERNMOST COUNTIES *of* SCOTLAND; *with some Observations on the* ORKNEY *and* SHETLAND ISLANDS.

By Sir R. I. MURCHISON, G.C.St.S., F.R.S., V.P.G.S., &c.

(PLATES XII. XIII.)

[Part II. of this memoir, read before the Geological Society on December 1st, 1858, and Part I., read February 3rd, 1858, have now, by permission of the Council, been united by the Author.]

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Introduction.—In this memoir I propose to give a general sketch of the succession of the stratified rock-masses which occupy the northernmost counties of Scotland, or those of Sutherland, Caithness, and Ross, followed by brief notices on the Orkney and Shetland Isles, as determined by former and recent observations.

Having commenced to labour in this region in 1826, I then simply gave, as a first result, the account of the Oolitic coal-field of Brora, and of the Lias and Oolites of both the east and west coasts, including the Hebrides, with brief allusions to the bituminous schists of Caithness containing fossil fishes*. For, although I even then had traversed portions of the crystalline rocks, I considered all such masses as out of the sphere of my observation, presuming that their mineral and other characters had been adequately made known by Macculloch and others who were looked upon as authorities. In short, it was deemed a sufficient effort for a young geologist, as I then was, to point out the relative position of certain members of the Secondary series, to collect their organic remains, and to show the relations of such strata to their equivalents in England.

In the following year Professor Sedgwick and myself, devoting our efforts to the examination of the structure of the Northern Highlands, produced a memoir in which, after a brief allusion to the older and crystalline rocks, we gave the first account of the true order of the Old Red Sandstone and superposed masses, which we then showed to consist of three parts, viz. Lower Sandstone and Conglomerates, Central Caithness Flagstone, and overlying Red Sandstones of Dunnet Head and the Orkney Islands†. In that same summer we also traced the position of the so-called primary limestones of Assynt and Durness, and ascertained that these were intercalated in great bands of quartz-rocks and surmounted by chloritic, micaceous, and even gneissose strata. We further affirmed that those crystalline masses, together with the granite and other igneous rocks which traversed them, had afforded the materials out of which the conglomerates and sandstones at the base of the Old Red Sandstone of the East Coast were formed. Thus far our original views have proved to be true. Owing, however, to stormy and wet weather which we encountered on the west coast of Sutherland, and our limited time, we were precluded from observing the true relation of certain vast masses of red conglomerate, which, occupying lofty mountains, have recently been shown to underlie the quartzose and crystalline limestones just

* Trans. Geol. Soc. 2nd ser. vol. ii. p. 313.

† I had visited the Orkneys during the previous year.

spoken of. In spite of torrents of rain, we had, however, observed that some of the sandstones and coarse grits of the West Coast were associated with such crystalline rock; but, unable to follow up the observation, we laboured under the erroneous conviction, in common with all our contemporaries, that the great mountainous masses of red conglomerate and sandstone of the West Coast were simply detached portions of the Old Red Sandstone of the East Coast, as they had been represented to be by all preceding authors. Nor was this inference to be wondered at; for at that time both Prof. Sedgwick and myself were entirely unacquainted with the true succession of the Lower Palæozoic Rocks below the Old Red Sandstone. This opinion respecting the age of the conglomerates of the West Coast remained, indeed, so fixed in the minds of all succeeding geologists, including Hugh Miller, that even in my own work, 'Siluria,' published in 1854, these North-Western conglomerates and sandstones, which I had not then revisited, were considered to be of the same age as those of the true Old Red on the East Coast of Scotland. In fact, notwithstanding the very able researches of Cunningham, in addition to those of Macculloch and Hugh Miller, no one had obtained a correct notion of the general order of those older rocks of the N.W. Highlands.

Just at that period (1854), my friend Mr. Charles Peach, already distinguished by discovering those fossil remains in the hard quartz-rocks of the maritime headlands of Cornwall* which enabled me to assign them to the Lower Silurian age, being sent from his Custom-House station at Wick to visit a wrecked ship on the north coast of Sutherland, discovered certain organic remains in the limestone of Durness, which, though imperfect, were unquestionably shells.

Now, as I had previously expressed the opinion that large portions of the so-called primary or crystalline rocks of the Highlands of Scotland would prove to be equivalents of Lower Silurian deposits in the south of Scotland †, I naturally felt anxious to revisit the spot where the important discovery had been made. Having requested Professor Nicol to accompany me, the results, as related to my own views, were given at the Glasgow Meeting of the British Association in 1855. Having procured some additional fossils (one of them a chambered shell), I then still more held to the opinion, that the quartz-rocks and their subordinate limestones were of Lower Silurian age. I also seized that opportunity of maintaining the dignity of the Old Red Sandstone of the N.E. of Scotland as a great geological series, and asserted my opinion, that it is the true and full equivalent of the Devonian group of other countries.

Still two essential points remained to be distinctly cleared up. Professor Nicol and myself had noted the infraposition of a red conglomerate and sandstone to the quartz-rock and limestone; but, foiled by heavy rains and mist, we could not follow out the line of junction, and ascertain the persistence of such order in the adjacent

* Trans. R. Geol. Soc. Cornwall, 1849, p. 103; and Quart. Journ. Geol. Soc. vol. viii. pp. 5, 13.

† Quart. Journ. Geol. Soc. vol. vii. p. 169.

mountains. Aware that Col. James, R.E., was about to visit that region early in the summer of 1856, to select a site for the purpose of observations on the density of the earth, I requested him to trace that line of junction. This he did successfully as regarded the mountains of Suilven and Queenaig, and showed, in a letter to myself, that the red conglomerate and sandstone were *unconformably* overlapped by the quartzite series. Later in the same summer of 1856, Professor Nicol greatly extended our previous observations, and drew those clear sections which are published in the Journal of the Geological Society*, showing that the old gneiss and its superposed conglomerate, as seen along a very extensive region of the Western Coast, formed really the buttresses upon which all the crystalline quartz-rock and limestone of the western parts of Ross-shire and Sutherlandshire reposed.

It was thus that the very high antiquity of the red conglomerate and sandstone of the whole of the N.W. Coast was determined; for not only was it shown to underlie strata which, as I had suggested, would prove to be of Lower Silurian age, but the edges of such subjacent conglomerate and sandstone were seen to have been eroded before such Silurian deposits had been laid upon them.

Having agreed with me as to the facts respecting the ascending order of, 1st, an underlying or old gneiss; 2nd, great red conglomerate and sandstone; and, 3rd, the quartzites and limestone with overlying gneissose rocks,—Prof. Nicol, influenced by the mineral analogy of a fossiliferous limestone being intercalated in quartzites which he rightly considered to be merely altered sandstones, suggested, theoretically, that these quartzose and calcareous rocks might prove to be the equivalents of the Carboniferous series of the south of Scotland, in which limestones are also enveloped in sandstones. But my associates will recollect that my fellow-labourer (than whom no man is more impressed with the desire to ascertain the whole truth) simply put forth this hypothesis until all doubt should "be removed by the discovery of better-preserved characteristic fossils†."

In thus speculating, Prof. Nicol thought that the imperfect fossils on which I had reasoned were inadequate grounds for my hypothesis. He was also unconvinced of the accuracy of my inference, as based upon a datum which I held to have been fixed long before by Sedgwick and myself, and to which I still adhere, viz. that the above-mentioned crystalline rocks, in parts of which the fossils have recently been found, are the *inferior* members of the great undulating mass of gneissic and micaceous rocks, which, rolling over to the East Coast, there constitute the basis out of which the bottom strata of the deposit known as "the Old Red Sandstone" are chiefly formed. Though still sceptical on this latter point, and waiting for a more accurate survey of the country than has hitherto been made, Prof. Nicol bows now to the fresh evidences of organic remains, and considers, with myself, that the quartz-rocks and limestones of the west of Sutherland are of Lower Silurian age.

* Vol. xiii. p. 23.

† See Nicol, Quart. Journ. Geol. Soc. vol. xiii. p. 36.

Another theory, which had been previously propounded by the lamented Hugh Miller, was, that the quartz-rocks and marble limestone of Sutherland might be the metamorphosed representatives of the Old Red and Caithness series on the East*. Independently, however, of the organic remains, both these views seemed to me to be incompatible with the physical order of the masses. For, if Sedgwick and myself did not err in supposing that the true Old Red of the East Coast reposed upon and was made up of the materials of an upper portion of these quartzose and micaceous rocks, it was manifest that such original strata could not be the equivalent of *either* of the posterior formations!

Seeing that the question would be still more satisfactorily settled if better fossils than those which Mr. Salter and myself believed to be Lower Silurian were obtained, I induced my friend Mr. Peach to renew his search and devote more time to it; and the result was a second collection of such well-defined forms as dispelled all doubt, and enabled me unhesitatingly to say that the suggestion I offered at the Glasgow Meeting of 1855 is absolutely correct, and that the rocks in question are truly Lower Silurian. Under these circumstances, I offered a general sketch of what I considered to be the order and succession of the older rocks of my native country, the Northern Highlands†.

Feeling, however, that there still remained several points which required a stricter examination, I again visited the North of Scotland in the summer of 1858. On that occasion I induced Mr. C. Peach to be my companion in the counties of Sutherland and Caithness, as well as in the Orkney and Shetland Islands‡; and I have only to regret that official business deprived me of his valuable assistance when I examined the more southern counties of Ross, Inverness, Moray, Banff, &c.

One of my main objects was to ascertain whether the view taken by Professor Sedgwick and myself thirty-one years ago, respecting the age of the yellow sandstones of Elgin, Morayshire, which we had grouped with the Old Red Sandstone, was correct. It was, in short, of great importance to determine whether the air-breathing lizard (the *Telerpeton*) which had been found in these rocks was really of that remote age, or whether these light-coloured sandstones might not pertain to the Oolitic and Liassic series, masses of which occur

* This view was propounded before the Physical Society of Edinburgh and printed in the *Witness* newspaper. The author was so obliging as to furnish me with a printed copy of the memoir, from which I have extracted the admirable description of the sandstone and conglomerate mountains of the West Coast, given at page 363.

† Read before the Geological Society, February 3, 1858.

‡ The officers of the Commissioners of the Northern Lighthouses were so kind as to convey myself and companion from Scapa Bay near Kirkwall, in Pomona, through the other Orkney Islands which I had not visited, to the furthest point of the Shetland Islands, and finally to disembark my companion and self at Cape Wrath, where we recommenced our survey of the North-west of Scotland. I shall ever remember with delight the society of Mr. Alexander Cunningham, the Secretary, Mr. Thomas Stevenson, the masterly engineer of the Lighthouses, and of Mr. W. Swan, the Mathematician, and Mr. Grant, the Registrar.

on the opposite side of the Murray Firth. In consequence, I re-explored part of my native county of Ross, and, thence passing into Morayshire, there made researches in the endeavour to fix the age of the yellow sandstones containing lacertine remains, and in this I was zealously assisted by my friend the Rev. G. Gordon, of Birnie. I followed the Old Red deposits into Banffshire, and was satisfied that the fish-bearing beds of the Spey, Tynet-burn, and Gamrie, occupy, like the Caithness flags, a central position in the Old Red series, and do not constitute the lower division, as had been previously stated in all geological works.

Lastly, in examining the same series as exhibited on the S.E. of the Grampians, I was convinced that the grey flagstones of Arbroath and Dundee, and the flanks of the Sidlaw Hills, there form the base of the same natural group, and that the Red Sandstone of Perth graduates up into those yellow sandstones of Fife, which, being charged with certain fishes peculiar to the deposit, are distinct, on the one hand, from the central or Caithness beds of Old Red Sandstone, and from the lowest beds of the Carboniferous System of Scotland on the other. The following observations will not be given in the order of my tours, but by beginning with the oldest rocks and ascending to the youngest, as in preceding communications.

In offering this general view, I beg my associates to dwell chiefly on the facts adduced, and not to judge a memoir which relates particularly to the northernmost counties of Scotland, with a few allusions to the Orkney and Shetland Islands, by the incidental expression of my own speculative opinion respecting the more southern parts of the Highlands. Let me add, however, that even that addition has not been solely drawn from the few leading data to which allusion is here made, but is the result of several visits to different parts of the country. My companion in the year 1827, Professor Sedgwick, will recollect how, on the summit of Ben Wyvis, we then regarded its micaceous and gneissose flagstones with little other interest than as parts of those rocks out of whose debris the lower conglomerate of the Old Red Sandstone had been formed. Little did we then anticipate that in a few years we should both be actively engaged in the classification of various formations of much higher antiquity than the Old Red Sandstone, then regarded by us with such veneration, and which by their order and organic remains would enable geologists to decide upon the real age of the stratified crystalline rocks of the Highlands!

In concluding this introduction, which may at the same time be considered a *résumé* of the facts to be detailed in the memoirs which follow, a few words only need be said upon the great change which must now be made in all geological maps of the Highlands of Scotland. The gneissose and quartzose rocks, limestones, chloritic schists, micaceous schists, indeed, may remain as lithological subdivisions of groups; but the order of the *legend* attached to Macculloch's Geological Map of Scotland must be essentially changed, for Lower Silurian fossils are now known to occur in rocks near the bottom of the primary crystalline scale.

Not pretending to define the exact boundaries of the formations as now divided, I have still endeavoured to colour roughly a little geological map* of the Northern Counties and the Orkney Islands (Pl. XII.). In doing this, I have separated the old or fundamental gneiss from the younger quartzose and Lower Silurian series, with which Macculloch had merged it, by interpolating a great formation of Cambrian age, and have shown that the true Old Red Sandstone, overlying all those rocks, is marked by that triple division which so distinguishes it in Caithness and the Orkney Islands.

In treating of the Old Red Sandstone, I trust that the endeavour which I have made to demonstrate that the strata with *Cephalaspis Lyellii*, *Pterygotus Anglicus*, and *Parka decipiens*, which really lie at the base of all that series, are certainly of higher antiquity than the bituminous fossil-bearing schists of Caithness, will meet with the approbation of my associates.

The separation of the older and younger gneiss is, of course, easily effected in those tracts, where, as along a large portion of the North-west Coast, the great intervening conglomerate and sandstone of Cambrian age, as well as certain Lower Silurian rocks, occur; but there are doubtless more points than are known to me, in the interior or eastwards, where the old gneiss may be at once covered by younger rocks without the intervention of any such conglomerate or sandstone. In short, the general section (fig. 1) is to be considered as the diagrammatic sketch of my own views respecting the true order of succession, founded on data obtained by other inquirers as well as by myself.

The reader will well understand that some such view as is here presented is absolutely called for in order to clear up the scepticism which prevailed in the minds of the most eminent geologists respecting all the so-called Transition rocks before the new classification, as established upon superposition and organic remains, was propounded. So strongly was this felt, that in his last work, 'A System of Geology,' published in 1831, Macculloch thus writes:—"As the nature and boundaries of this class [the Transition rocks] have never yet been defined or proved, I have not given it a place in this work among the facts of geology. Yet if it really should be established by future and better observations, I shall owe the science an apology to which I cannot yet consider any geologist entitled†."

Fundamental Gneiss.—The most ancient stratified rock in Scotland, and, as far as I know, in the British Isles, is that gneiss which is exhibited in the north-western shores of Ross and Sutherland, where it forms the rugged basement of the whole stony superstructure, and has been well described by various authors, from Macculloch and Jameson to Cunningham. This rock is, even mineralogically, distinguishable from a younger metamorphic rock, which has also

* This map will be issued in a subsequent Number of the Journal, it being my intention to revisit the Highlands this summer, in order to satisfy myself still further on some doubtful points,—particularly in respect to the Reptiliferous sandstones of Moray.

† *Op. cit.* vol. i. p. 469.

Fig. 1.—*Diagrammatic Section, showing the General Succession, in ascending order, across the North Highlands from W. to E.*
(Distance about 85 miles.)

a. Fundamental grey gneiss with red granite-veins. *b*. Chocolate- and red-coloured Cambrian conglomerate and sandstone. *c*. Lower Silurian rocks, consisting of—c^1, Quartz-rock with *Annelides*; c^2, Limestone with fossil shells; c^3, capping of quartz-rock. *d*. Crystalline schists and flagstones, occasionally chloritic and micaceous, often quartzose, and sometimes constituting flaglike gneiss, though in some spots they are little-altered flaglike sandstones. [* Igneous rocks, whether granite, syenite, porphyry, or greenstone, &c. These occur at various horizons, and are in some places interstratified and contemporaneous, and in others eruptive. Thus, large-grained porphyry occurs below *a* and *b*; greenstone and hypersthenic rock, with serpentine, are associated with *c*,—particularly c^2; syenitic and porphyritic rocks protrude between *c* and *d*; whilst these and true granites of several varieties, forming larger masses, burst through *d*, and are alone represented in this generalized section; the stratified rocks in contact (*d**) being highly altered and dislocated.] *e*. Lower conglomerate and sandstone of the Old Red Series, made out of all the above-mentioned rocks. *f*. Caithness ichthyolitic flagstones, or middle beds of the Old Red. *g*. Upper Old Red Sandstone of Caithness and the Orkney Islands, Tarbet-ness, &c.

been called gneiss, and has not as yet been distinguished from the older gneiss on any map, though the two are separated by vast formations of Cambrian and Lower Silurian age. (Compare this order with that of the maps of Macculloch and Cunningham †.)

It is, however, well exposed, as forming the low maritime headlands of Sutherland and Ross. This old gneiss is here and there traceable to Cape Wrath and the western side of Loch Eriboll. It is also represented in the woodcut, fig. 1, as lying beneath Cambrian red sandstone and conglomerate. The same order extends southwards along the west coast of Rossshire ‡. The prevalent strike of this old gneiss is E.N.E.–W.S.W., the strata being variously inclined at high angles, and highly contorted. The body of the rock, being usually hornblendic, is also often penetrated by powerful granitic veins. This older and massive gneiss, usually of darker grey colours and of greater specific gravity than the younger rock hereafter to be described, is seen to subside to the east beneath the overlying formations, whether they consist of red conglomerate and sandstone, near the West Coast, or of quartz-rocks with limestone and mica-schists that appear at a short

† Transactions of the Highland Agricultural Society, vol. for 1839.

‡ See Nicol, Quart. Journ. Geol. Soc. vol. xiii. p. 19.

distance eastwards. It will be for future geologists to observe the extent to which this old rock may rise to the day in the central or eastern portions of the Northern Counties of Scotland. For, although I have been unable to detect its reappearance in Sutherland or Ross-shire to the east of the tracts extending from the west side of Loch Eriboll to Loch Assynt, it may well reappear in various parts of the wild and trackless interior which I have not explored. This old gneiss often occupies platforms of no great altitude, and for the most part constitutes those low, rounded, bare hills which resemble in outline the waves of a rolling sea. The spectator who, ascending to the summit of Ben Stack (one of the loftiest points reached by the old gneiss in Sutherland, and 2363 feet above the sea*), looks westward, observes, between him and the sea of Scourie Bay, a countless quantity of small lochs or tarns interspersed among the hollows of this brown-clad barren and rugged waste. On descending to examine the lower tract, he finds the surface frequently rounded off and polished like the "roches moutonnées" of the Alps; and, observing numerous striæ or scratches usually divergent from the central mountains, and following the lines occupied by the principal lakes or maritime fiords, he can have no doubt that, in the glacial period, the North-west of Scotland must have been very much in the present state of Greenland as described by Rink,—*i. e.* the central mountains occupied by snow and ice, from which vast glaciers are protruded to the lateral fiords or bays.

Whether it be examined at Cape Wrath on the shores of Loch Laxford, or in the bold cliffs near Scourie opposite the Island of Handa, in the Kyles of Strome or in the Bay of Loch Inver, the older gneiss has everywhere the same grey hornblendic basis, traversed by many veins of bright-pink granite. In ascending from the village of Loch Inver to Drum Swordalan, the geodes and veins of hornblende are indeed so rife as to constitute the chief masses of the rock.

This old gneiss chiefly occupies the cliffs along the western shore of the Kyle of Durness; and in a little burn adjacent to the Ferry House, the rock is charged with asbestos and actinolite.

Cambrian Red Sandstone and Conglomerate of the West Coast.—The ancient gneiss (*a*) of the general diagram (fig. 1) is seen in

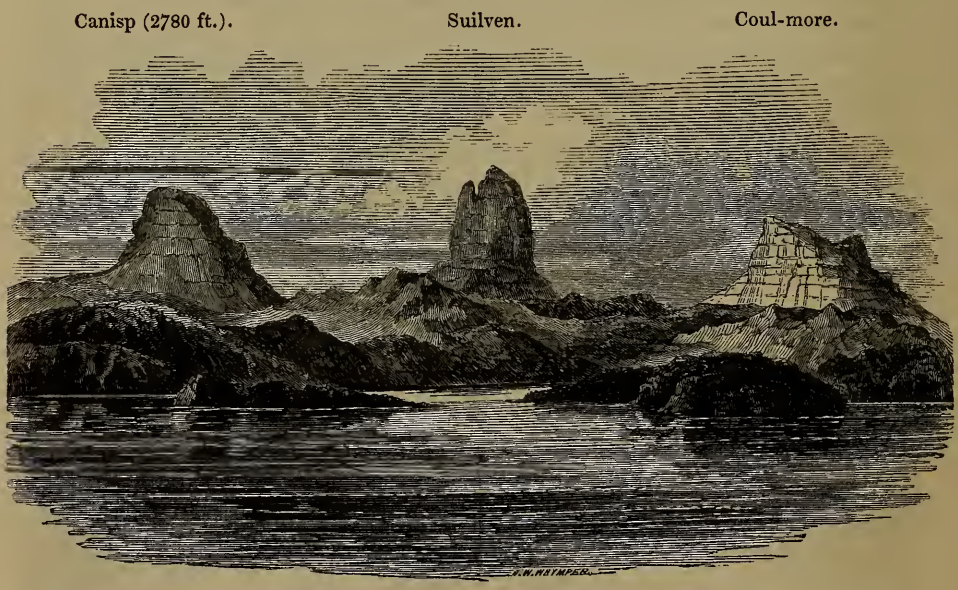
* By the kindness of Col. James, the Superintendent of the Ordnance Survey, I have been favoured with the following list of the heights of the principal mountains in Sutherland, which cannot but prove useful to the readers of this memoir, and those interested in the physical structure of the North-western Highlands:—

	Feet.		Feet.
Ben Clibrig	3157·6	Ben Horn	1708·4
Ben Hutig	1340·0	Ben Armin	2332·3
Fashven	1495·7	Ben Hie	2862·3
Cnoc Ghuibhais	975·7	Ben More in Assynt	3235·5
Suilven	2396·1	Canisp	2780·2
Ben Stack	2363·8	Ben Spionno	2535·4
Carnstackie	2629·2	Arkle	2578·3
Sarwhal More	2548·9	Ben Hope	3040·7
Foinaven	2979·1	Glashven	2542·9
Ben Laoghal	2505·5	Queenaig	2673·0

many places along the north-western coast of Sutherland and Ross to be surmounted by great masses of dull-brown, red, and chocolate-coloured sandstone and conglomerate (*b*). This superposition is peculiarly well exhibited in the lofty and pyramidal mountains of Coulmore, Suilven, Coulbeg, Canisp, and Queenaig. When viewed from a boat at sea, these relations are precisely as Macculloch described them, and just as they are shown in fig. 1. But whilst their inferior relations were long ago well known, it has only been recently ascertained, as explained in the Introduction, that, as a whole, these north-western conglomerates and sandstones lie *unconformably* subjacent to the series of quartz-rocks with fossiliferous limestone ($c^1\,c^2\,c^3$) as well as to the micaceous, gneissose, and chloritic schists (*d*) which occupy so large a central portion of the Northern Highlands.

The conglomerate and sandstones of the North-west Coasts, which occupy this low position in the geological series, and which have on the whole a strike from N.N.E. to S.S.W., are, in truth, similar in lithological character to the purple and chocolate-coloured grits and pebble-beds of the Longmynd, which in the earlier days of our science were termed "Compound Sandstone" by Townson, and which were subsequently described at some length by myself, when I first showed that they formed the real base of all the Silurian series of Shropshire and the adjacent counties (see 'Silurian System,' p. 253, pls. 31, 32, and 'Siluria,' new edit. p. 23).

Fig. 2.—*Mountains of the West Coast of Sutherland and Ross.*
(From 'Siluria,' new edit. p. 198.)



These rocks, as they appear on the coast of Sutherland, have been so truthfully and poetically described by Hugh Miller (though he then, like myself, thought they were Old Red Sandstone), that in

reproducing this woodcut from 'Siluria' I willingly transcribe the words of that lamented author:—

"Rising over a basement of rugged gneiss hills that present the appearance of a dark tumbling sea [the dark lower rocks of the preceding sketch], we descry a line of stupendous pyramids from 2000 to 3000 feet in height, which, though several miles distant in the background, dwarf by their great size the nearer eminences into the mere protuberances of an uneven plain. Their mural character has the effect of adding to their apparent magnitude. Almost devoid of vegetation, we see them bared by the line of the nearly horizontal strata, as edifices of man's erection are bared by their courses of dressed stone; and, whilst some of their number, such as the peaked hill of Suilven, rise at an angle at least as steep and nearly as regular as that of an Egyptian pyramid, in height and bulk they many times surpass the highest Egyptian pyramid. Their colours, too, lend to the illusion. Of a deep red hue, which in the light of the setting sun brightens into a glowing purple, they contrast as strongly with the cold grey stone of the gneiss tract beneath, as a warm-coloured building contrasts with the earth-tinted street or roadway over which it rises *."

The occurrence of powerful red conglomerates on the south-western parts of the coast of Scotland, as shown by Mr. Carrick Moore and myself to be intercalated in the Lower Silurian rocks †, has indeed already prepared us for this identification of these still older Cambrian conglomerates as rising out to the north-west of the same country, where, resting upon the oldest known gneiss of the British Islands, their eroded surfaces are irregularly overlapped by quartz-rocks and limestones which are proved by their fossils to be of Lower Silurian age.

The local distribution of these Cambrian conglomerates and sandstones of the North-western Highlands, whose maximum thickness as exposed to day is not less than from 2000 to 2500 feet, is demonstrated by the fact, that, in proceeding a few miles only to the east, or into the interior, the fundamental gneiss is either laid bare or is seen to be at once covered by the powerful quartz-rock and limestone series, to the exclusion of those Cambrian rocks which range from various western headlands of Ross-shire to the bold promontory of Cape Wrath in Sutherland ‡.

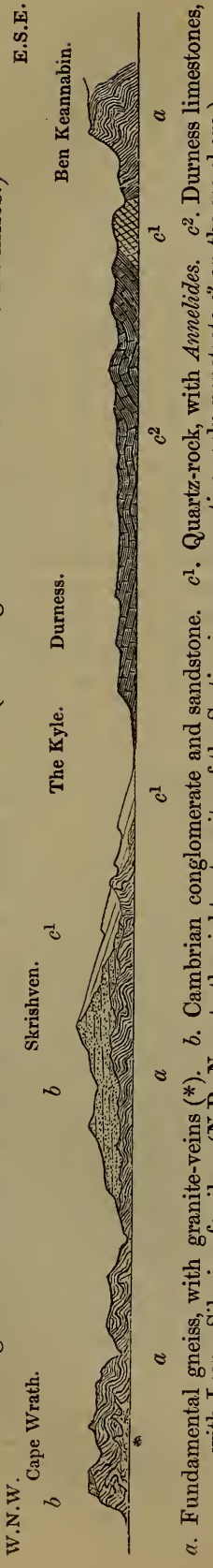
At Cape Wrath, which I had not visited since the year 1827 (when the lighthouse was building), I observed, on its western slope and summit, that the rocks of old gneiss were covered by beds of finely rounded pebbles, which disintegrate into very fine gravel. These beds of the Cambrian rock dip away very slightly (8°) to the W.N.W.,—all the pebbles in this conglomerate varying in size from one inch to $\frac{1}{4}$ of an inch, and being made up of fragments of the subjacent old gneiss. In following the coast-ridges to the east, or the Kyles of Durness, the lowest strata of the rock (*b*) are seen to graduate up into the usual red- and purple-coloured hard sandstones

* This description was read before the Physical Society of Edinburgh in 1854, in the memoir in which Hugh Miller propounded the theory respecting the quartz-rocks and limestones, to which allusion is afterwards made. The whole was printed in the 'Witness' newspaper, and transmitted by the author to myself with an explanatory letter.

† Quart. Journ. Geol. Soc. vol. vii. p. 149; and vol. xii. p. 359.

‡ See Trans. Geol. Soc. 2nd ser. vol. iii. p. 155.

Fig. 3.—*Transverse Section across the Durness Basin.* (Looking North. Distance about 14 miles.)



a. Fundamental gneiss, with granite-veins (*). *b*. Cambrian conglomerate and sandstone. c^1. Quartz-rock, with *Annelides*. c^2. Durness limestones, with Lower Silurian fossils. (N.B. Near to the right extremity of the Section igneous eruptive rocks penetrate c^2 on the sea-shore.)

which on the west rise from the cove of Clashcarnach to the summit of Skrishven (1213 feet above the sea), on the eastern flank of which they are unconformably overlapped by the lowest beds of the quartz-rock (c^1), which dip away to the E.S.E. and form the base of the Lower Silurian rocks of Durness, as shown in the Section, fig. 3.

In the interior of the tract called the "Parph," or the mountainous district lying between Durness on the N.E. and Loch Laxford on the S.W., these Old purple sandstones are largely developed, also capping the fundamental grey gneiss. They are indeed well exhibited near the summit-level of the high road to Scourie, or at the Gwalin Inn, whence they are seen to pass under the great quartzose Silurian series on the east. They extend, however, very little further to the east, since the gneiss rising in the western flanks of Foinaven and Ben Stack is at once covered by the lower quartz-rock. The Cambrian sandstone is again magnificently displayed in the western cliffs of the Island of Handa, where it constitutes cliffs upwards of 500 feet high, much frequented by sea-fowl, and where the strata, slightly deviating from horizontality, are also laid open by fine vertical fissures; the dip inclining, on the whole, a few degrees to the S.E. Again, in the promontory of Rhu Storr, or the Point of Assynt, and all along the shores of Lochs Inver and Enard, the fundamental gneiss is unconformably superposed at a little distance inland by masses of the Cambrian Red Sandstone, which, to the south of the Kyles of Strome, rise into the lofty peaks forming the chief beauty of the tract of Assynt and constituting from north to south the detached mountains of Queenaig, Suilven, and Canisp, each separated by lower tracts of fundamental gneiss, as in the preceding woodcut, fig. 2, and thence extending into similar ranges in Ross-shire. On this occasion I explored carefully (the weather favouring) the eastern flanks of Suilven, where the nearly horizontal strata of that noble mountain are seen in their greatest extent to repose upon the fundamental gneiss. It is about halfway along the side of the mountain that the whole mass has been affected by a great E. and W. fault, to which my attention was first called by Colonel James.

The upland longitudinal depression separating Suilven from Canisp is in its lowest part occupied by Loch Ganiveh, the old gneiss hills on the sides of which offer many fine examples of the polishing, scratching, and rounding action of a glacier which must have passed along the gorge. In proof that the movement was towards the sea, we found at Loch Inver many blocks of that large crystallized felspathic porphyry which my active and zealous companion, Mr. Peach, had in the previous year traced around the flank of Canisp. As seen from the shepherd's hut called Clacharie, the chocolate-coloured bands of the lofty Suilven are partially fretted by pendent stalactites like icicles, whilst a few green grassy slopes occur at intervals, to give greater effect to the marked horizontality of the whole, which is strikingly contrasted with the highly inclined gneiss on which it rests. Here the base of the sandstone is a coarse brecciated conglomerate. The fault traversing this mountain, and which at a rough estimate seemed to me to be an upcast to the south of from 800 to 1000 feet, is, as far as I could judge, parallel to a great fault in the adjacent mountain of Canisp, observed by Mr. Peach.

Whilst the unconformability of the Old Gneiss to the Cambrian Sandstone is everywhere manifest, an equally clear discordance is exhibited between the latter and the overlying quartz-rocks; and of this feature many examples will be presently given.

In the depression between Canisp and Suilven, Mr. Peach detected the existence of the strong band of red porphyry, with large crystals of felspar, which is interposed between the gneiss and the great conglomerate*. Thus, one of the earliest coarse sedimentary accumulations in the crust of the globe seems to have been ushered in by the eruption and spreading out of porphyry associated with red conglomerate,—a phenomenon which has been repeated at intervals through the Silurian and Devonian periods to the conclusion of the great Palæozoic era, and strikingly during the accumulation of the Permian deposits. The pebble-beds of the North-western Highlands, though traceable for a considerable distance along a given north and south zone (evidently an ancient line of shore), diminish rapidly if followed on their dip, and are thus seen to be accumulations, which, though of great thickness in some spots, thin out and disappear in the course of a few miles. In no country is this feature better seen than in following these Cambrian conglomerates of the N.W. Highlands to the E.S.E., when we distinctly see, as has just been said, the fundamental or old gneiss at once covered by the quartz-rock series, to the entire exclusion of any remnant of the old shore pebbles with their coarse grits and sands, which, at a few miles only to the west, clearly underlie all the quartz-rock series. The range of these conglomerates southwards along the western shores of Ross-shire has already been well detailed by Prof. Nicol; and his sections are so clear that I have simply to refer the reader to them†.

* Prof. Nicol has also noticed the presence of porphyry associated with the same rocks in Loch Broom. See Quart. Journ. Geol. Soc. vol. xiii. pp. 20, 21, 35.

† See Quart. Journ. Geol. Soc. vol. xiii. p. 23.

Lower Silurian Rocks (c^1, c^2, c^3), *in the form of Quartz-Rocks with intercalated Crystalline Limestone, followed by Chloritic and Micaceous Schists, and Younger Gneiss.*—These consist (in ascending order, as exhibited in the general section at p. 360) of—1. quartz-rock (c^1); 2. limestone (c^2); 3. quartz-rock (c^3); (d) micaceous and chloritic schists passing into a sort of gneiss, with repetitions of quartzose and micaceous flaggy rocks, &c.

Such is the succession observed in proceeding from the districts of Ullapool, Assynt, and Durness on the west, to the south-eastern border of Sutherland, where that county is bounded by Ross. With some local deviations and rolls which reverse the inclination, the prevailing dip of all these regularly stratified masses is eastwards, and for the most part to the E.S.E. or S.E. Let us first consider the inferior members of this group, as exhibited on the shores of Loch Broom and at Ullapool in the north-western extremity of Ross-shire, and as ranging thence to the N.N.E. through the wide parochial tracts of Assynt and Edderachillis, into Durness, throughout which they can be more or less continuously followed for a distance of not less than fifty miles, and always exhibiting the same order of a central mass of limestone with underlying and overlying quartz-rock strata, succeeded upwards by mica-schists and a younger gneiss.

Lower Quartz-rock.—The lowest beds, as seen in the west of Sutherland, rest, as before said, on the Cambrian conglomerate and sandstone (b), or, if that formation be absent, on the old gneiss (a). Their lithological characters have recently been so well described by Nicol under the name of *quartzite**, that I have little to add. Fine-grained, void of mica, and usually of a light-buff or greyish colour, but often weathering to a pure white, this siliceous band much resembles the Stiper Stones of Shropshire, and gives the clearest evidence that it is simply an altered sandstone, being not only regularly bedded and jointed, but also exhibiting here and there argillaceous way-boards, which have usually passed into schists. This band further resembles the Stiper Stones or the typical base of the Silurian rocks of Shropshire in containing Annelides (Pl. XIII. figs. 28–31) and Fucoids, which last also occur in the uppermost layers of the lower band and immediately beneath the limestone.

The minute cylindrical bodies which Macculloch supposed to be Orthoceratites have completely satisfied Mr. Salter that they belong to the class of sea-worms. I have therefore named them, in the new edition of 'Siluria' (1859, p. 222), *Serpulites Maccullochii*, in honour of the first discoverer of the oldest perceptible organic remains of the Highland rocks. (See Pl. XIII. fig. 31.) At the Bridge of Skiag, near Loch Assynt, an argillaceous course occurs upon the lower quartz-rock, containing casts of tortuous cylindrical bodies which are evi-

* I prefer adhering to the old name of Quartz-rock, by which these rocks have been known from the early days of Scottish geology, and which I long ago applied to the Lower Silurian Stiper Stones, showing that they were altered sandstones (Sil. Syst. p. 268 *et seq.*). The term "quartzite" has been adopted from the French.

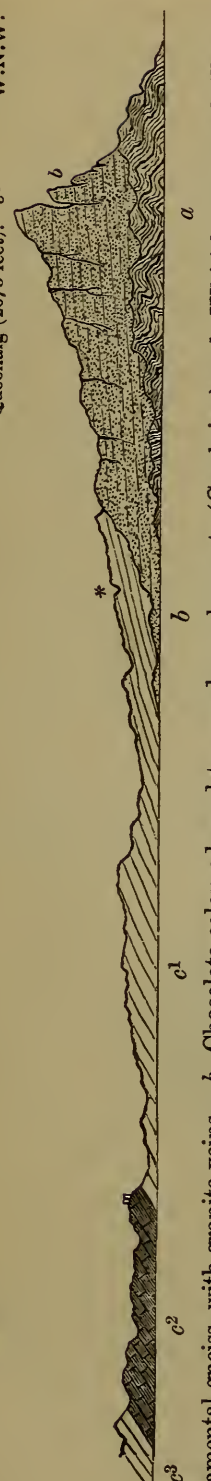


Fig. 4.—*Transverse Section across the Assynt Country.* (Looking South. Distance about 6 miles.)

a. Fundamental gneiss, with granite-veins. *b*. Chocolate-coloured sandstone and conglomerate (Cambrian). c^1. Whitish quartz-rock (Lower Silurian), with *Annelides*. * Position of the large Annelide-tubes. c^2. Dark-coloured limestone, containing chambered shells (Lower Silurian). c^3. Quartz-rock, capping the limestone.

dently referable to marine plants or fucoids * ; but nowhere has anyone—not even the keen-eyed Peach—collected a form which can be referred to terrestrial vegetation. The exact position of the *Serpulites Maccullochii* and the Fucoids, as thus given, is to be traced over a considerable area, both in the environs of Assynt and in those of Loch Eribol.

It is to be observed that the siliceous courses in which annelides occur, are not to be considered a porous granular quartz, as stated by Macculloch, but as a hard compact rock which simply becomes porous upon weathering, when the fossils are best exposed.

Instructive sections in ascending order may be made, either from the Kyles of Strome or from Loch Inver, in Sutherland. The former, however, is by far the most satisfactory, because, by slight deviations only from the road, the passing traveller may satisfy himself of the truth of all the data of superposition. Quitting the rugged bosses of gneiss at the Ferry, and ascending to the summit-level of the road, he soon meets with layers of the chocolate-coloured Cambrian sandstone, which, sweeping down to the road from the lofty precipices of Queenaig, dip to the W.N.W. at the slight angle of 5° or 6°; so nearly do the beds of that very ancient rock approach to horizontality.

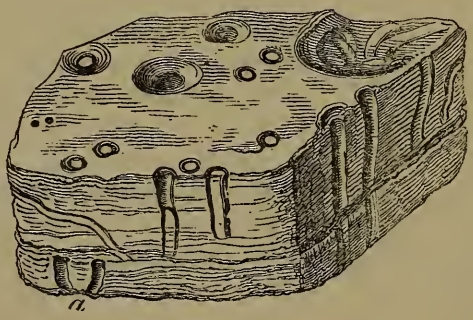
Here there is no ambiguity; for the chocolate-coloured Cambrian rock is clearly superposed by sheets of the compact quartz-rock, which dip from 20° to 25° to the S.E. In short, no unconformity can be more striking; and the quartz-rock, at the summit-level of the road, rests on the shoulders

* The fucoid-bed and its associates were traced by Mr. Peach from Ledbeg near Loch Awe, by Stronchrubie, Inchnadampf, Assynt, Bridge of Skiag, and thence towards Kyle Scow, and at two of these places Prof. Nicol and myself had previously detected it. Mr. Peach observed them in precisely the same position on the eastern shores of Loch Eribol.

of the hill, then rises high upon the truncated edges of the Cambrian rock, and even caps one of the summits of the noble Queenaig. The lower beds of the quartz-rock, which rest upon the Cambrian sandstone, are here very striking, from exhibiting on their surface large round knobs on the tops of cylindrical bodies which pass through several layers and are unquestionably the infillings of excavations made by *Annelides*. (See Pl. XIII. figs. 29, 30.) The quantities of these pipe-shaped bodies are astonishing; and as they also occur in the same stratum (*i. e.* near the base of the lower quartz-rock) and on the west shore of the Kyle of Durness, we may infer that they are the oldest vestiges of life which can be detected in the Lower Silurian rocks of the North Highlands.

In illustration of the manner in which these tubular bodies traverse the layers of quartz-rock or crystallized sandstone on the north-eastern flank of Queenaig, I may here repeat a woodcut from p. 41 of 'Siluria' (new edit.), representing Annelide-burrows in the quartz-rock of the Stiper Stones, a well-known Lower Silurian rock of Shropshire. The trumpet-shaped openings, sometimes 2 or 3 inches in diameter, the tubular cavities, and the cylindrical casts (identical with forms found thirty years ago on the west shore of the Kyle of Durness by Sedgwick and myself), leave no room for doubt that they also represent the *Annelides* of the English Stiper Stones and of the Potsdam Sandstone or Lowest Silurian rock of North America (*Scolithus linearis* of Hall).

Fig. 5.—*Fossil Annelide-tubes* (Scolithus linearis) *from the Stiper Stones, resembling those from Assynt.* (From 'Siluria,' new edit. p. 41.)



Descending into the Vale and Loch of Assynt, upon the surface of the lower quartz-rock, its upper layers are clearly seen to become more schistose and shaly, and also to exhibit fucoidal and other impressions. Then the succeeding limestone expands in terrace over terrace, and is best exposed in mounting from the edge of the loch, or from the west by north, to the hill called Cnoc-an-drein, on the east by south. In this walk you pass over a succession of parallel ridges for the space of about three-quarters of a mile, each calcareous band dipping easterly at about 25°. Some of the limestone is of deep-grey or dull-blue colour; other parts are light-grey,

whitish, and mottled: portions of it have been formerly opened out for marble-quarries. As Mr. Peach detected an Orthoceratite, there is little doubt that future researches in this rock will bring other fossils to light. In approaching its summit, the limestone becomes more impure, its uppermost band bearing a peculiar aspect, and intermingled with schist and shale,—some courses resembling volcanic ash or grit.

These beds are at once, as at Eribol, overlaid by beds of whitish and pinkish fine-grained quartz-rock; and thus in one and the same escarpment, and only a mile from the Inn of Inchnadampff, the limestone is seen to be fairly intercalated in the quartzose series; the last mounts up by Brebeg into the lofty mountains of Coniveall, which passing to the S.S.W. constitute a range of mountains that extends into Ross-shire.

On this last occasion we did not follow the Lower Silurian limestone further to the S.S.W. than Elphin, where, although it is partially changed into a white, hard, compact marble in the vicinity of certain eruptive rocks (syenite, porphyry, &c.), it still occupies precisely the same place in the series,—the lower quartz-rock being seen to sweep down in broad sheets from the Cambrian sandstone mountains of Suilven, Coulmore, and Coul Beg, and to be surmounted, at the base of the limestone hill of Knockin, by the mottled fucoidal shale-bands.

Durness and Assynt Limestone.—The lower quartz-rock, with its cap of fucoid- and serpulite-beds, is everywhere surmounted, in Durness as in Assynt, by a strong band of limestone, which, under the scrutiny of Mr. Peach, has afforded those organic remains which have enabled us to pronounce unhesitatingly that these rocks are of Lower Silurian age. Hard, marbled, veined, and occasionally divided by joints, this grey limestone is often highly siliceous. Not only does it assume in parts a cherty character, but in Durness it is filled with a profusion of geodes of chert or quartz, which assume fantastic shapes, and weather to a darker exterior than the body of the rock.

There, in a less well-preserved condition, some of the fossils, which were at first found at one or two spots only, have recently been detected by Mr. Peach in other localities of that extensive parish. The manner in which many of the fossils have been filled with siliceous matter and the manner in which the organic remains weather under such conditions, offer a striking analogy to the aspect presented by North American specimens derived from strata of the same age in Canada, and transmitted by Sir W. Logan.

In the environs of Inchnadampf, and particularly to the east of that place, the limestone forms noble terraces resting upon the lower quartz-rock, and is clearly overlaid by other quartz-rocks, which rise into Ben More of Assynt and other lofty mountains. The same order is seen at the Bridge of Skiag and other places, the fucoidal and shale beds always occurring in the upper portion of the lower quartz-rock; whilst on the road to Durness the whole ascending order is exposed, from the old gneiss upwards, when the spectator looks to

the E.S.E. from the marine bay called the Kyles of Strome, over the mountains ranging into the interior*.

In Durness, beds of pure and very impure, highly cherty, and cavernous limestone alternate with altered schists and finely granulated and laminated hard siliceous sandstone of divers colours, both red and grey, as exposed in ledges upon the shore near Balnakiel. These hard and tough rocks are interlaced with geodes marking the lines of stratification, as well as by thin courses of flinty chert. The concretionary structure is well exhibited at Craig Sarsgrun, about three miles south of the Durin Inn†, where the concretions vary in size from an inch to several feet in length. The concretions are often white, sometimes pink, and therefore present a striking contrast to the dark-grey escarpment. Many of these beds are almost quartz-rock; but as they contain some calcareous matter, the natives usually call them all "limestones."

The geologist can easily detect the calcareous portions by the weathering of the escarpment, which presents partially eroded lines along the course of the small concretions. These rocks are all more or less affected by a slaty cleavage, which, being highly inclined, disposes the rock to jut out in sharp protruding bosses through the green sward by which the calcareous band is characterized.

Although the ascending order of the quartz-rocks and limestones is everywhere the same as in Assynt, *i.e.* a strong band of limestone interposed between masses of regularly stratified quartz-rock, the subjacent Cambrian conglomerate disappears in Durness, and the lower quartz-rock rests at once upon the old and fundamental gneiss. This is seen on the west shore of the Kyle of Durness, and also near Rispond upon the coast, in the escarpments of Ben Spionno in Durness, and at other places in the interior to the S.S.W., *i. e.* Ben Stack, &c. The western face of Ben Spionno is indeed entirely composed of the lower quartz, which, sloping down to the east by south to Loch Eribol, is there seen to dip under the limestone of the Chorrie Island and to form fine calcareous terraces along the eastern side of the loch. These limestone-bands are in their turn overlaid by other quartz-rocks. (See fig. 3, p. 364.)

During my last visit to the North-west in company with Mr. Peach, I confirmed what is stated in the previous sentences. Thus, proceeding from the district of the Parph, or from Cape Wrath on the W.N.W. to Durness on the E.S.E., the succession exposed in the accompanying section is admirably seen. The older gneiss and Cambrian sandstone (*a* and *b*) have been already spoken of; and of the

* Previous to my last visit, Colonel James had re-assured me that the limestone extending from Assynt to the N.N.W., by Glendhu, Mealhorn, Loch Dionart, and Camvel, to the eastern shore of Loch Eribol, occupies everywhere the same position I had assigned to it as subordinate to the white quartzose beds. The best section which he examined, in reference to this part of the succession, was along the course of the Lone River, which falls into Loch Stack; and there an overlying as well as an underlying quartz-rock is clearly exposed.

† The Inn of Durin, kept by Mrs. Ross, is strongly recommended to explorers, as also the Inns at Loch Inver, Inchnadampf, and Scourie.

eroded edges of the latter is seen to repose the lower quartz-rock (c^1) in thin flat-bedded strata usually weathering white, but here and there of a pinkish colour. It was in the higher part of this band that Professor Sedgwick and myself (1827), and Macculloch before us, observed certain cylindrical bodies, now known (as before observed) to be due to *Annelides*. Dipping to the E.S.E., these rocks are carried under the great mass of the limestone of Durness (c^2), which occupies several ridges over a maximum width of about three miles.

Examining its ridges both longitudinally and transversely, Mr. Peach pointed out to me, and particularly in the hard, cherty, and cavernous portions of the rock, many *Maclureæ* and a great abundance of *Murchisoniæ*, with some *Orthocerata*. These fossils invariably occur in dark-coloured cherty and very fetid limestone, which occasionally presents a rugged outline as it peers through the rich grass of this sheep-feeding-ground. Some of the exposed points or knobs, which weather black, are surrounded or partially wrapped over by a tufa-like siliceous sinter, sometimes resembling a breccia, which conveys the idea of a boiling over of such matters when the rock underwent the metamorphism to which it has evidently been subjected. Even in this peculiarly hard matrix, my companion detected traces of fossils. The most marked of the external characters of the limestone is its coarse rugosity—the result probably of weathering upon its peculiar composition, and which gives the scarps of the rock the appearance of an elaborately wrought rustic basement of a Florentine palace. The best limestone is in the state of a cream-coloured compact marble; but no fossils have been discovered in that variety of the rock. Even in its siliceous condition, the limestone occasionally retains an oolitic structure.

Owing to breaks, undulations, and twists, it is difficult to form even a tolerably accurate estimate of the united thickness of all these beds of limestone; but in Durness, where they occupy successive terraces with little intervening grassy valleys, they cannot well be less than 500 or 600 feet thick. If the section be extended to the Old Bishop's Castle on the east (fig. 6), the observer finds that, after passing over

Fig. 6.—*Section of the Upper Quartz-rock to the east of Durness.*

c^2. Durness fossiliferous limestone.
c^3. Quartzose and micaceous flagstones.

a low ground covered by blown sand (the usual position of the upper quartz-rock in other places), he reaches a headland composed of overlying thin-bedded grey micaceous flagstone (c^3), which occasionally weathers white, like the promontory of the Whiten Head on the opposite side of the bay.

No one who has advanced from the west to the east, and left behind him the old gneiss, can for a moment fail in recognizing the distinction between this overlying crystalline flagstone and the old gneiss, though it also contains felspar as well as quartz and mica: it is not hornblendic and massive, and is void of granitic veins. In other localities, to be considered presently, it will be seen how the limestone is directly superposed by a band of pure white quartz-rock. One of the best detailed sections, showing the succession of the limestone, is seen to the north of the House of Balnakeil, and in some of the northernmost headlands, places in which Mr. Peach collected many of his fossils. Previous to my last visit, I had supposed (and Professor Nicol had published a section to show it*) that the Durness limestone was abruptly cut off by the old gneiss upon the east, between Durness and Loch Eribol. But such is not the case; for Mr. Peach had observed, and I confirmed his observation, that between the interior ridge of old gneiss which extends from the western foot of Ben Keannabin and the limestone of Durness, the dip is reversed, and the underlying quartz-rock is again brought up, lying between the gneiss and the limestone, as represented in the section, fig. 3, p. 364.

The reversal by which the Durness limestone is thus placed in a trough of quartz-rock and overlying limestone has been manifestly occasioned by a great upheaval of the old gneiss when acted upon by eruptive forces, of which clear signs are manifested in the adjacent Bay of Sangoe. There huge bosses of black hornblendic and hypersthenic rock stand out with serpentinous coatings,—the courses of the limestone in their vicinity being singularly altered, mottled and dolomitic.

Again, as we ascertained that Farred or Far-out Head consisted of the old gneiss, there is now no doubt that the limestone and underlying quartz-rock of Durness occupy a trough. The clearest proof of the trough-shaped arrangement of the strata is a little to the west, or inland, from the well-known limestone promontory in which the large caves of Smo occur. This limestone, which dips very slightly seawards or N.N.E., is highly altered, siliceous, and prismatized by a number of vertical lines of rude cleavage, which cause the rock to split into innumerable brittle fragments. On leaving the headland, and on mounting to the low-peaked hill of the quartz-rock called Sangoe Beg, certain white cherty and siliceous beds are remarkable as graduating into the lower quartz-rock, which is seen to rise gradually from under the limestone until the beds attain the high angle of 65°, the dip to the N.N.E. being traversed by the same rude vertical cleavage. A deep gully here alone separates the quartz-rock from the older gneiss.

Quitting the basin of Durness, including the large limestone island of Hoan, and passing across the noble longitudinal marine loch of Eribol, the geologist who proceeds to the E.S.E., or towards Ben Hope or Loch Tongue, has thenceforward a clear and unmistake-

* Quart. Journ. Geol. Soc. vol. xiii. p. 23. fig. 4.

able ascending section from the fundamental gneiss, which ranges from Ben Spionnach to Loch Soan on the west side of Loch Eribol. For he there sees the lower quartz-rock dipping to the E.S.E. from off the shoulders of the older gneiss hills, and even from the summit of Ben Spionnach, 2204 feet above the sea, and then plunging under the limestones of Island Chorrie and Eribol, as described on a former occasion.

As it had been doubted by Professor Nicol whether the quartz-rock which I had described as regularly overlying in some places the limestone of Durness, Eribol, and Assynt was not cut off from the latter by dislocations, I especially explored, in my last visit, the coast-ridge on the west side of Loch Eribol from the Ferry to the north. In that direction, or in the northerly strike of the beds, the limestone, which at first occupies several low hills resting upon the lower quartz which flanks the sea, thins out gradually to a very small band which under Cnoc Craggin and to the north of Heilam is seen to be fairly interpolated between the lower and a band of upper quartz-rock,—the latter being pure white, and all the strata dipping to the E.S.E. at about 18°.

In the hills extending towards the Whiten Head, where all the strata are exposed on the sea-cliffs, we pass over, in ascending, first the upper beds of the lower quartz-rock, charged with the Annelide-tubes and the *Serpulites Maccullochii*, and graduating up into the limestone by impure calcareous strata, and then the limestone itself with Fucoid-shale. Now all these beds of quartz-rock and included limestone are, I maintain, covered, as a whole, by the micaceous flagstones, schists, and younger gneiss of the higher hills, and these clearly extend to the Kyle of Tongue and the flanks of Ben Hope. The last-mentioned lofty mountain is indeed almost entirely composed of such micaceous flagstones (*d* of the sections), all of which have hitherto been mapped under the name of gneiss. The strata on the west shore of the Kyle of Tongue are literally almost sandstones.

In this way I not only satisfied myself that the section of 1827, showing a younger micaceous and gneissose flagstone series over the limestone of Durness and Eribol, was correct, but also that the latter, like many other Silurian limestones, was an accidental deposit, subordinate to a great siliceous or quartzose series. In fact, the limestone, so expanded at Durness as to occupy a wide basin, as well as on the large island of Hoan, thins out and disappears in a quartzose series as we proceed from Eribol towards the Whiten Head or the N.N.E.

In its longitudinal range from Loch Eribol to the South of Assynt, or for a distance of about forty miles from N.N.E. to S.S.W., the limestone performs precisely the same part, showing itself occasionally in thin courses only, either pinched out or scarcely traceable, but always fairly intercalated in the quartzose and crystalline rocks.

Thus, when not covered by moss and heather, the limestone crops out at several spots to the S.S.W., as at the head of Loch Eribol

and in the Bealloch or depression between the grand mountains of Fionavin and Meal Horn,—the former composed of the lower quartz resting on old gneiss, the latter of the overlying flaggy and micaceous series. The limestone occupies a similar geological position to the east of Arkle and Ben Stack. There, though only visible at intervals through the thick covering of peat and heather of a deer-forest, the beds of limestone are to be observed dipping steadily to E.S.E. and quite conformably to the underlying quartz-rock, which slopes down in brown masses from the shoulders of Arkle and Ben Stack; the former exhibiting noble white precipitous faces on the S.S.W. The banks of Loch Stack and Loch More, extending from N.W. to S.E., naturally expose transverse sections of this regular succession from the fundamental gneiss through this overlying Lower Silurian series, —the Cambrian rocks having again thinned out and disappeared, as in Durness.

Ascending the mountain of Ben Stack, 2363 feet high, we found that the old gneiss, of which the mass is composed, was covered by a pebbly band, which formed the base of the quartz-rock, and passed eastwards into overlying sheets of the same; and these, on both the north and south shores of Loch More, are covered by thin bands of limestone, which in their turn, and particularly on the south side, are followed by siliceous flagstones, occasionally used for building, while to the north some of these rocks are used as hone-stones. Nowhere, in short, in all this range, is the limestone placed in a trough by a reversed dip, as in Durness, all the strata being invariably inclined to the E.S.E., whilst the masses lying to the east, though occasionally gneissic, are on the whole very different from the old or fundamental gneiss.

The limestone reappears in its course to the S.S.W. at the head of the Lochs of Glendhu and Glencoul, and thence passes into Assynt, where it again expands, as in Durness, into a mass of considerable thickness, and is there more clearly exposed between masses of quartz than in most parts of its northern range.

Fossils of the Durness Limestone.—Mr. Salter has supplied me with the following description of the Organic Remains from the Durness Limestone.

CEPHALOPODA.

Orthoceras mendax, spec. nov. Pl. XIII. fig. 24.

This form comes nearer to Hall's figures of *Orthoceras multicameratum* (Pal. New York, vol. i. pl. 11) than to any other species we are acquainted with; and as the smooth *Orthoceratites* are so difficult to identify, it would have been more satisfactory to me to have left it with that species, than propose a new specific name. But in the adult portion of our shell there is an appearance of annulation, which cannot be altogether due to the state of the fossil, for it is too regular; the younger portion, in an equal state of preservation, appears quite smooth. The contradictory appearances have suggested the name.

General form very gradually tapering, with shallow close annulations ($\frac{1}{8}$th of an inch apart in a diameter of $\frac{3}{4}$ of an inch) in the older portion, in the young nearly smooth. Section circular. Septa numerous, close-set, one to each annulation in the older part; at a diameter of 4 lines there are 15 to an inch. They are only slightly concave, and bent down somewhat angularly* towards the siphuncle, which is excentric, thick, smooth-edged (not at all beaded), and compressed in a direction from front to back. It also has a shallow groove along the side nearest to the centre of the shell, so as to give in section a somewhat bilobed form (fig. 24 *b*).

Specimens from Canada, of what I believe to be *O. multicameratum*, resemble this shell so strongly in the young part, and have so similar a siphuncle, that it is difficult to regard them as different species; they, however, taper more suddenly.

Orthoceras arcuoliratum, Hall.

(Palæont. New York, vol. i. pl. 42. fig. 7.)

Fragments of this species resemble those from Canada and N. America, with oblique and sinuous rings; and, though imperfect, differ decidedly from other forms accompanying them which have direct annulations, and which I refer to the species next described.

Orthoceras vertebrale, Hall? Pl. XIII. figs. 22, 23.

(Hall, Palæont. New York, vol. i. pl. 43. fig. 5.)

The specimens are much smaller than those figured by Hall, and have a circular section and central siphuncle when young; the annulations, however, are narrower and more prominent.

One specimen (fig. 22), with very slightly oblique rings, is compressed; it has blunter and broader rings than the other. None of Hall's figures strictly agree with it; but it might be the young state of *O. bilineatum* of that author.

Orthoceras undulostriatum, Hall. Pl. XIII. figs. 25, 26.

(Palæont. New York, vol. i. pl. 43. fig. 7.)

Although the side-view of Prof. Hall's figure 7 *e* has not the rings quite so oblique as in this specimen, I do not think it a distinct species, for the dorsal view quite agrees, and the rings have about the same degree of convexity, with a slight keel along their middle, more conspicuous in the weathered specimens.

The septa appear to have a sinus on the dorsal surface like that of the rings—a character quite unusual in *Orthoceras*. But the Cephalopoda of this very old Silurian zone present many abnormal characters, such as the extraordinary size of the siphuncular tube, and its being filled up with solid or cellular tabulæ. One of the most singular of all these shells is the species next described, and for which I am obliged to institute a new genus.

* Very much in the way that Hall represents them in his figure of *O. multicameratum*, *op. cit.* pl. 11. fig. 1 *d*.

PILOCERAS *, gen. nov.

A broad, conical, and slightly curved shell, subcylindrical (or compressed). Siphuncle and septa combined as a series of conical concave septa, which fit into each other sheathwise.

PILOCERAS INVAGINATUM, spec. nov.

Pl. XIII. figs. 17–21; and Woodcut, fig. 7, *c*.

P. 5 uncias longum, conicum, subcurvum, ore ovali, (long. oris ad lat. ut 11–8).

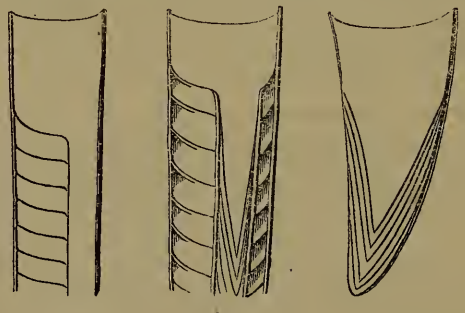
This singular shell, which seems to offer the simplest of all Cephalopodous forms (and to combine in its septal plates both septum and siphuncle), is not unfrequent in the Durness limestone, in a silicified state. None of the several specimens collected by Mr. Peach are perfect.

The mouth is oval, with the longer diameter about 2 inches, and the breadth $1\frac{1}{2}$ inch, in specimens which would measure above 4 inches long. The general form is gently curved, ending in a somewhat obtuse point (fig. 19), near which the tube is annulated rather strongly, while in the older portions it is more faintly so.

The septa, at a diameter of $1\frac{1}{4}$ inch, are rather more than one $\frac{1}{5}$th of an inch apart, and viewed in section (fig. 21) show only three concentric sheaths. There is clear evidence only of four septa in the longitudinal section (fig. 20), the remaining lines being due to the crystallized linings of the chambers. These septa end in a sharp point downwards, the walls meeting at an angle of about 35°, or less.

Comparison is naturally sought for this remarkable genus among the numerous Cephalopods of the same zone. In America the *Orthocerata* with large lateral siphuncles (woodcut, fig. 7, *a*) abound,

Fig. 7.—*Diagram of some forms of Lower Silurian Orthoceratidæ.*



a *b* *c*

a. Cameroceras. *b*. Endoceras. *c*. Piloceras.

and in some of these the diameter of the siphuncle is so great in proportion to the size of the shell, as almost to realize the form now under consideration. *Endoceras proteiforme*, Hall, Pal. New York, vol. i. pl. 48, &c., and still more *E. magniventrum*, pl. 53, show not only a great siphuncular space, but also a pointed termination of the siphuncle itself (fig. 7, *b*), which thus appears as an elongated lobe or process of the hinder part of the body, like one of the many lobes of

* From πῖλος, *a cap*, and the usual termination κέρας.

the Goniatite or Ammonite, but specialized for a certain end. I had occasion to point out this in a paper on a peculiar Cephalopod, *Tretoceras**, which has, in addition to the ordinary siphuncle, a long posterior lobe extending through *seven* or more of the septa. In some of Hall's figures of *Endoceras* (*op. cit.* pl. 44, for instance, if not in pl. 19), there are indications of a forked or triple termination to the long siphuncular lobe, the cavity behind being filled up by solid deposits. Hence there is an appearance as of one or more *Orthocerata* being contained in the large siphuncle. The fossils called *Hyolites*, in the Silurian rocks of Sweden, are believed to be similar internal casts of siphuncles.

In *Piloceras* the continuity of the hinder part of the body with the siphuncular lobe is complete, and only ordinary septa (not solid masses) are secreted from its surface. There is no appearance of any external shell to which these conical septa might have appertained as a broad siphuncle.

We have then, in this fossil, what I believe to be the simplest form of Cephalopodous shell; and it is very suggestive that it should occur at the base of the Silurian deposits (the lowest in which *Cephalopoda* are known) both in Britain and Canada†, and be accompanied in these beds by genera, like *Endoceras* and *Cameroceras*, which connect it with the ordinary forms of Orthoceratite.

Piloceras ——?

There are not specimens enough to characterize a small species which occurs of this genus, an inch or two long, and of a cylindrical tapering form. The septa are of the same shape as those above described.

Oncoceras? Pl. XIII. fig. 27.

The specimens are so imperfect that we cannot tell if the mouth be really much contracted or not, or of what form the apex is. The latter is but slightly curved, and the shell increases gradually and regularly towards the terminal chamber, which is somewhat longer than broad, and appears to be inflated. The septa are concave and oblique, rising highest against the dorsal (shorter) side, and so close together that seven lie in the space of a quarter of an inch. The siphuncle is rather large and external.

The American species, *O. constrictum*, is more curved and more contracted at the mouth, and it has more distant and straighter septa. Our fossil is referred very doubtfully to *Oncoceras*.

GASTEROPODA.

Maclurea Peachii, spec. nov. Pl. XIII. figs. 1–5.

M. triuncialis, valde depressa, umbilico latissimo; anfractibus 5–6, infra planatis, supra rotundatis subangulatis; operculo longo spirali.

This fine shell is distinguished immediately from the other known *Macluræ* by its very flat shape, the discoid whorls scarcely over-

* Quart. Journ. Geol. Soc. vol. xiv. p. 177.

† In the Calciferous Sandrock. Billings (in letter), 1859.

lapping each other at all, and exposing nearly the whole of the great umbilicus* (fig. 2). The whorls on this, the upper, side are convex, subangular a little beyond the middle, and abrupt on the margin of the umbilicus; the width of the last whorl in comparison with the preceding is as 7 to 4. On the lower side (fig. 1*a*) about five are visible; the inner ones are more equal in size, the second being scarcely twice the width of the third. A raised sutural ridge runs round the inner margin, and (unless this be due to pressure) the centre of the whorl is somewhat angular also.

The operculum (figs. 4, 5) is widely different from that of *M. Logani*†, having the nucleus produced in the most extraordinary way, and spirally rolled. The appearance is that of a gasteropod shell (*Capulus* or *Pileopsis*) unrolled; but by comparison with fig. 6, which represents the operculum of *M. Logani*, the corresponding areæ may easily be traced. The lower edge (*a*) is nearly straight, to correspond with the flattened base of the mouth, and the ridges which correspond with the inner angle (*e*) and base (*d*) of the mouth are only very much stronger than in the Canadian species. Coarse rough lines of growth cover the surface, and antiquate the whole of the operculum. The umbo (*b*) is much more produced in some specimens, and incurved in a remarkable degree. All the specimens have the inner process broken away. The chief figure (1*a*) has the operculum added to it in outline (1*b*), to show what position it appears to have occupied in the full-grown shell. Fig. 3 is a restored outline-view, seen edgewise.

The resemblance of *Maclurea* to the genus *Caprotina* or to *Caprinella* will at once be evident; and it was to this group, the *Rudista*, that Mr. Woodward was first inclined to refer the genus. He has, however, included it in the *Heteropoda* as a solid form, probably sedentary, and allied to *Bellerophon*.

Ophileta compacta. Pl. XIII. fig. 12.

(*O. compacta*, Salter, Decades of the Geol. Survey of Canada, Dec. I. pl. 3.)

As this interesting and very peculiarly-formed shell has been fully described in the work above quoted, the details need not be repeated here. In the Durness limestone it occurs generally of a smaller size than in Canada, though we have one imperfect specimen (not figured) an inch broad. The under side (*a*) is perfectly flat, the upper (*c*) deeply cup-shaped, and the cast of this surface (*b*) is of a dome-like form, with deep notches at the sutures of the whorls.

On a careful comparison I can find no essential difference between the British shell and the Canadian one, except the less rapid growth of the whorls. In a specimen from Beauharnais, near Montreal, $1\frac{1}{4}$ inch wide, the proportion of the last whorl to the preceding is as 3·75 to 2. In one from Durness an inch broad, the propor-

* Not the real umbilicus, as in other shells, but rather the sunk spire (Woodward). The shell is not a reversed one,—the flat side is the under side.

† 'Decades, Canadian Survey,' vol. i. pl. 1. In these figures, as also in our own, the shells are represented in an inverted position—the characters being more easily shown in that way.

tion is 3·25 to 2. This difference is probably in exact accordance with a less favourable nature of the locality, which did not permit of rapid growth or the attainment of full size.

Ophileta levata, Vanuxem, besides being a small species, has more numerous whorls, and appears to have a narrower umbilicus.

EUOMPHALUS (MACLUREA) MATUTINUS, Hall?

(Palæont. New York, vol. i. pl. 3. fig. 3.)

Several small specimens in the Durness limestone appear to correspond with the species which accompanies *O. compacta* in Canada; but no stress should be laid on the identification of so obscure a fossil; it may be a representative form only. Another and somewhat larger species is found with it. There is, besides, a large *Raphistoma*, like *R. labiata*, Emmons, and scarcely distinguishable from it.

PLEUROTOMARIA THULE, spec. nov. Pl. XIII. fig. 13.

P. vix unciam lata, pyramidata (ad apicem 45°), suturis inconspicuis; carina prominula, angusta, subplana; anfractibus 5–6, striis supra obscuris, infra profundis exaratis; basi subplana, ore rhomboideo.

About five lines high, and the same breadth at base, of a pyramidal shape, the five or six whorls regularly conical, and scarcely distinct at the sutures except by the prominent narrow band. The whorls are nearly smooth above the band, or crossed only by very oblique curved lines of growth; but below the band they are very rough and prominent over the nearly plane base. The band itself is rather prominent, angular above and below, but with no depressions or keels upon its surface; it is crossed by strong arched lines of growth. The mouth appears to be regularly rhomboidal.

Many palæozoic species resemble, yet are not identical with, this shell. It is only necessary to compare it with one allied species, to which at first sight it is likely to be referred, the *P. subconica* of Hall's 'Palæontology,' vol. i. pl. 37. fig. 13. That species, however, as figured, has a much more prominent and rather ventricose base, and is moreover transversely and closely striated, the striæ on the keel being collected into two distinct ridges, which margin the keel and make it almost a double one. There is nothing of this in our species, which has also more numerous whorls. If Hall's figures 8 *d*, 8 *e*, be of the same species, the resemblance is closer; but these are only internal casts; and his fig. 8 *a* is evidently the type specimen.

Four specimens, of which two are figured, occur near Balnakill in Durness.

MURCHISONIA (HORMOTOMA*) GRACILIS, Hall; var. GRACILLIMA. Pl. XIII. figs. 7, 8.

(Palæont. New York, vol. i. pl. 39. fig. 4. *M. angustata, op. cit.* pl. 10. fig. 2.)

It is not certain that this form is identical with those given by

* Proposed in 'Decade I., Geol. Survey Canada' for the elongate beaded forms of *Murchisonia*.

Prof. Hall in his volume; but believing, as I do, that both the figures above quoted belong to one species, I do not see enough in the more elongated form of our fossil to induce me to describe it as more than a variety.

In the ventricose and slightly angular whorls there is the closest resemblance; but, if their greater number and the consequent more tapering form of shell be considered as specific, it may retain the name *M. gracillima*, and will stand as a representative species. The length of our largest specimen is 1 inch 4 lines, and in that length there are 14 volutions; in a Canadian one of the same length not above 10 or 11. As we have not the exterior, it is safest to leave it as a variety.

MURCHISONIA ANGULOCINCTA, spec. nov. Pl. XIII. figs. 9, 10.

M. vix uncialis angustissima, anfractibus numerosis brevibus transversis perangulatis, angulo submediano; ore rotundato.

This is decidedly a different species from the last, and, though imperfect, possesses sufficient external character to allow us to distinguish it by a name.

It is far more elongate than *M. gracilis*, and of more numerous whorls than any species yet described, having, in a length of $\frac{3}{4}$ inch, 13 whorls, all of which are angulated, the upper ones strongly so. The angle is rather below the middle of the whorl, and the upper portion is somewhat concave, while the base is convex beneath it. Mouth rounded. The specimens are much worn.

MURCHISONIA BELLICINCTA, Hall? Pl. XIII. fig. 11.

(Palæont. New York, vol. i. pl. 39. fig. 1.)

The specimens are too imperfect positively to identify this shell; but the size and proportions are very much like those of Hall's species, especially his figs. 1 *a* to 1 *d*: fig. 1 *e* seems much more elongated.

BRACHIOPODA.

ORTHIS STRIATULA, Emmons. Pl. XIII. figs. 14–16.

(*O. testudinaria*, Memoirs Geol. Surv. vol. ii. pt. 1. pl. 27. fig. 8.)

Three specimens only have occurred of this characteristic Llandeilo-flag species. They are of the same size as those in Allumette Island, Canada, and more convex than usual in the species.

ANNELIDA. Pl. XIII. figs. 28–31.

In the quartz-rock of Durness, beneath the limestone, the abundant annelide-tracks have been already referred to (p. 366 & 368). It is only necessary to explain the figured specimens. Fig. 28 is one of the ordinary vermicular impressions so generally referred to worm-tracks or -burrows. In the present instance this is rendered more likely by the occurrence of some of the matter of the tube itself as a thin glossy film.

Fig. 29 represents a pair of those double burrows which are characteristic of shallow-water deposits through all the Palæozoic

series (see fig. 5. p. 368). They are known under the name of *Arenicolites*. Fig. 30 is a side-view of the contents of the burrow, and is trumpet-shaped above and striated on the sides.

Fig. 31. *Serpulites Maccullochii*, new species. (See 'Siluria,' new edit. p. 222.) Short, subconical, and curved tubes, of thick substance, and with but a slender central perforation. They were probably quite free, living in sand as does the recent *Ditrupa*, to which they are not unlike, except in the great thickness of the shell.

ZOOPHYTA.

There are fragments of two Corals—one of the Millepore group, and one probably a cup-coral, but too imperfect to identify; and many of the shells seem to be invested with a Sponge resembling the *Stromatocerium rugosum* of the Canadian rocks.

Note on the Fossils.—It will be observable, on glancing over the previous list, that the identifications with American fossils are not in many cases complete—certainly not so much so as a more cursory examination at first induced me to believe. And it may perhaps be that some of those here positively identified with species of the lower limestone of America may prove to be representative forms only when more perfect specimens can be compared. For example, *Orthoceras mendax* merely resembles *O. multicameratum*, Hall. *O. vertebrale* is but a doubtful identification, from imperfect specimens. *Oncoceras*, though of a different species, is an American genus. *Euomphalus matutinus* and *Raphistoma labiata*, if not identical, are at all events representative forms. *Maclurea Peachii*, *Murchisonia angulo-cincta*, and *Pleurotomaria Thule*, though new species, are closely allied to American forms.

On the other hand, there appear to be some, of the identification of which there cannot be much doubt: such as *Orthoceras arcuoliratum*, Hall. *O. undulostriatum* of our lists differs very little from the species so called. *Orthis striatula* is truly identical. *Ophileta compacta* and *Murchisonia gracilis*, with *M. bellicincta*, are others which I cannot separate from American species.

There are, then, *five identical*, three doubtful, four which may fairly be called representative forms (the *Maclurea*, the *Orthoceras*, *Murchisonia angulo-cincta*, and *Pleurotomaria*); and *Piloceras* is a new genus, found in Canada* and in Scotland.

That this truly North American assemblage should be found in the extreme north of Scotland, on the same parallel as the Canadian, —that species of *Maclurea* and *Raphistoma*, resembling those of the St. Lawrence basin, and *Orthocerata* bearing large siphuncles like those of N. America, Scandinavia, and Russia, should occur in Scotland, and yet be scarcely known further south, is at least suggestive of a geographical distribution—perhaps even of climatal conditions —not very unlike that of more modern times†.—J. W. S.

* The Canadian species is distinct.

† See the generalizations on this head, 'Siluria,' new edit. pp. 182, 507, *et seq.*; and Appendix, p. 553.

Overlying Micaceous Flagstones and Younger Gneiss.—In the masses which overlie the quartz-rocks and limestone, we no longer find the same uniformity of lithological composition as in the lower strata. In the earlier deposit, mica is absent; but in the higher masses, that mineral begins to prevail. Here and there, as we leave Assynt and Durness, and proceed to the E.S.E., it occurs in otherwise pure light-grey and whitish quartz-rock, and at others in dark-grey micaceous schists. Independently of dislocations and partial axes of elevation (one of which has been described as seen between Durin and Rispond, whilst another is met with at the south-eastern end of Loch Eribol, where granite protrudes), the micaceous part of the quartzose series is observed to be superposed, as a whole, to the group in which the limestones and their fossils occur. From Loch Eribol the strata have a persistent dip to the east by south. (See Section, fig. 8.)

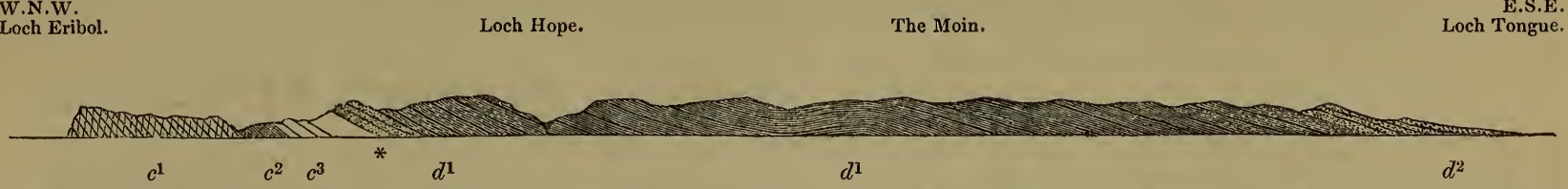
From the western coast-cliffs of Cape Wrath to the bay called the Kyles of Tongue, there can, indeed, be no sort of doubt that the whole series of quartzose and calcareous rocks which overlie the older gneiss and the Cambrian conglomerates, are, in their turn, covered by the younger micaceous flagstones of Inverhope and the Moin, and constitute one great series, the age of which is determined both by the order of superposition and by the fossils contained in one of its lower members.

It is still, however, necessary to call special attention to the upper portion of this group, which, though here and there a quartzose flagstone, also contains chloritic and micaceous schists, and occasionally exhibits so complete a mineral transition into a gneiss, that Macculloch in his map of Scotland, and after him Cunningham, grouped under one name the whole of these superior masses, as well as the great masses now shown to lie below the Cambrian and Lower Silurian rocks. In examining this country in the year 1827, my companion (Sedgwick) and myself distinctly noted both chloritic schist and flat thin-bedded gneiss as occupying several parts of the country, which we walked over in two directions, in the interior of this part of Sutherland; and we had no doubt that such rocks lay far above the limestones of Assynt. That careful and laborious observer, Cunningham, who examined the same tract after a long interval, took the same view. These same overlying rocks are continued, with some undulations, from the parallel of Tongue, on the coast, and Ben Clibrig, Lord Reay's Table, and Alt na Harrow, in the interior, to the frontiers of Caithness and Ross-shire on the E. and S.E.*

Usually thin-bedded and micaceous, they are formed, in certain places, of alternations of greenish- and greyish-coloured micaceous or quartzose gneiss, which present the external aspect of the Italian "Cipollino" or "onion-coated." Such rocks are seen at the escarpment of Ben Hope, in the heart of Sutherland, where they still dip

* The mountainous fringe extending from near Strathy on the north to Tomentoul on the south has not yet been examined by me; and I must abstain from including it in the same category; for it is by no means impossible that the older gneiss or fundamental rock of the N.W. may there be brought out again.

Fig. 8.—*Section of the Quartz-rocks, Limestones, and overlying Gneissose rocks, between Loch Eribol and Loch Tongue.*
(Distance about 10 miles.)



c^1. Lower Silurian quartz-rock, with *Annelides*. c^2. Limestone. c^3. White quartz-rock, capping limestone. d^1. Micaceous, gneissose, and chloritic schists, passing upwards (on the banks of Loch Tongue) into whitish micaceous flagstones, d^2.

[At the point in this Section which is marked by an asterisk, my friend Professor Nicol, who has revisited Sutherland this spring, has satisfied himself of the existence of a band of porphyry, occurring between the limestones and quartz-rocks which I have shown to be of Lower Silurian age and those varieties of schistose rocks, lying to the east, which I consider to be overlying, but which Prof. Nicol does not separate as a whole from the underlying gneiss. Though I have not yet seen the porphyry in question on the east side of Loch Eribol, I am aware of the existence of eruptive granitic rocks in about that position near the southern end of the Loch, and have also examined other eruptive rocks (syenite and porphyry) to the east of the calcareous and quartzose (Lower Silurian) rocks of Loch Assynt. Not doubting the accuracy of the mineralogical and physical observations of my able contemporary, I do not yet admit that the intercalation of any rock whatever of igneous origin can be brought forward as a reason for setting aside my facts and inferences as to the general order by which the crystalline rocks to the east of such dislocation overlie and are distinct in age from all the rocks which occupy the North-west coast of the Highlands. I have long ago been convinced that the general classification of deposits must be made, to a great extent, independent of all local phenomena of eruption and dislocation. Thus, in Wales, for example, there occur many extensive distortions along given lines, by which the Silurian strata are powerfully affected and dislocated without their general order of superposition being invalidated, whilst conformable masses of igneous origin are still more extensive. So in the Highlands, as explained in this memoir, a porphyry is intercalated between the fundamental gneiss and the Cambrian sandstone. In Durness the Lower Silurian limestone itself is penetrated by greenstone and serpentinous rocks. Then we have eruptive matter above the Lower Silurian limestones and quartz-rocks; whilst other eruptive rocks, whether porphyry, granite, or syenite, are seen to rise through that which I consider to be the overlying series at various horizons. With my present views, therefore, I see no reason whatever to alter my inferences; but, as I propose to revisit the North-west coast of Scotland during this summer, I hope to state the results at the ensuing Meeting of the British Association at Aberdeen. In the meantime, the reader will find in the various diagrams of the late Mr. Cunningham, who explored the north-west of Sutherland more in detail than any modern geologist, several sections showing an overlying gneiss conformable to the subjacent quartz-rocks and limestone, and wholly discordant to the inferior or fundamental gneiss. See "Geognosy of Sutherland," in the 'Trans. Highland Society of Scotland,' vol. xiii.—July 1, 1859.]

to the E.S.E., and contain garnets, whilst the lower part of the very same mountain is a true quartz-rock.

To the east of Tongue there is indeed a great sameness of such crystalline strata, which are inclined at low angles of not more than 10° or 12°; but at Naver the micaceous quartzose flags with garnets dip 60°, and at Farr as much as 70°. Thenceforward, in travelling eastward, intruding bosses of a granite similar to that noticed by Nicol and myself at the head of Loch Eribol again prevail; and some of these (as formerly described by Sedgwick and myself) not only penetrate the crystalline strata, but also throw off the overlapping Old Red Sandstone and Caithness Flags.

In Caithness the explorer enters into a region of essentially different structure, and consequently of an entirely different outline. In the very first quarries of the overlying sandstones and flagstones which he reaches, the traveller finds no longer a S.E. or E.S.E. dip, but one to the N. or N.W., or athwart the older rocky series on which he has been wandering. When the quartzo-gneissose series is followed southwards, by Ben na Ghream along the western flank of the flat and monotonous county of Caithness, we come to that remarkable group of mountains called the Scarabins, which are obviously a portion of the upper member of the same crystalline series. Here crystalline quartz-rock prevails, weathering pure white, and of a different character from the quartz-rocks of the west, being probably the result of the intrusion of the great masses of granite which there abound.

The manner in which the base of the Old Red Sandstone overlaps these quartz-rocks was long ago described by Sedgwick and myself *.

All around the Scarabins, and particularly to the east of Berridale, the most striking discordance is seen in the relative strike and dip of these two groups,—the quartz-rock, or associated gneissose strata, being inclined sharply to the W.S.W., or to the south by east, whilst the Old Red conglomerate and sandstone dip away east and north, and also to the west, at 10° and 12° only.

In like manner, when we proceed on the true dip of the older rocks from Loch Assynt on the W.N.W., and follow the course of the Oikel River from Sutherland into Ross, we meet with a great rupture and a complete unconformity of stratification at the junction with the Old Red Sandstone. Hence, setting aside partial disturbances at various horizons, as resulting from the eruption of igneous rocks, we see that all the crystalline and subcrystalline strata from the west up to this great and general break, and which are intercalated between the Cambrian Conglomerates beneath and the true Old Red Sandstone above, must belong to one and the same great natural division; for they are, on the whole, conformable to each other in their strike, undulations, and inclination. Even if no fossils had been found in them, it was probable that, being placed between a conglomerate of very high antiquity, on the lower or western side, and the base of the Old Red Sandstone on the other, these quartzose

* See Trans. Geol. Soc. 2nd ser. vol. iii. p. 128.

rocks, limestones, mica-schists, &c., would probably prove to be of Silurian age. Fortunately the discoveries of Mr. C. Peach have conclusively settled that question as respects one of their lower members.

A few observations are, however, called for in reference to a difficulty which has presented itself to the mind of Professor Nicol. Admitting, as he now does, that the quartzite group (which, from mineral qualities, he had suggested might be of Carboniferous age), is, as I supposed, Lower Silurian, he still doubts whether that group really passes under the micaceous flaggy rock or eastern gneiss. His doubts have been increased by finding, that along the line of junction there occur (particularly in the west of Ross-shire, at the head of Loch Maree) outbursts of igneous rock which he thinks are connected with a general dislocation along the strike.

But my observations do not support this view. See fig. 8 and its appended Note.

Such protrusions of igneous rock occur very irregularly in the North-western Highlands and at various horizons. Thus we have seen that in Canisp porphyry is associated with the lowest part of the Cambrian rocks; that hypersthenic rocks penetrate the limestones of Durness and the quartz-rocks and limestones of Assynt; that syenite and felspar-rocks again reappear above the Silurian limestones at Ledmore and on the banks of Loch Borrolan; whilst the powerful eruptive syenitic mass of Ben Laoghal penetrates the younger gneiss in the heart of Sutherland. Such eruptions do not, therefore, in any way specially cut off the fossiliferous Lower Silurian zone, but burst through overlying strata of different ages.

Compared, indeed, with the wide range of the stratified crystalline rocks, these eruptive or igneous masses are mere pustules, which in no wise derange the general succession, though they occasion partial rolls and folds of the beds near the points of local intrusion. Thus, in advancing to the S.E. from Assynt, we have no sooner passed the boss of syenite near Loch Borrolan and the inn of Alt-na-Gallagach, towards the E.S.E., than we are presented with the very same flaggy micaceous succession which is so clearly exposed between Lochs Eribol and Tongue. The eruptive matter is indeed very likely to peer out here and there along the lines of least resistance, or where one set of beds is overlaid by another.

On the high road leading from the west to Lairg and the Dornoch Firth, a limestone which I consider to be superior to any of the Assynt rocks is exposed at Cnoc Craigie*. Though affording no fossils under our hasty inspection, this rock, which is yellow and apparently dolomitic, clearly overlies all the light-coloured quartzite series, and is at once surmounted by dark-grey micaceous flagstones quite unlike any stratum beneath them. At the Bridge of Alt Ellag,

* I was informed, by a very intelligent man who had accompanied the Surveyor who made the map of Sutherland, that the limestone of Cnoc Craigie reappears to the N.N.E. at Kinloch Ailsh and Fianloch More, at the west end of Loch Shin; and that freestone reoccurs in this flag-like series at Ben Skillachor, north of Loch Griam.

at Loch Craigie, and again at Lub-croy, these flaggy micaceous rocks are well exposed, at the last-mentioned place assuming a gneissose aspect. They are all perfectly conformable, all dipping steadily to the S.E. or E.S.E., and are completely distinct, even in mineral characters, from any of the underlying rocks, whether old gneiss, Cambrian, or the quartzose and calcareous Lower Silurian group. They are, in short, dark micaceous flagstones, which to the N.N.E. range across the upper end of Loch Shin, and thence in the same direction extend to Ben Hope until they occupy the expanse of country between Lochs Eribol and Tongue. See fig. 8, p. 383.

If the banks of the Oikel be descended until that river falls into its marine estuary at Bonar Bridge, the succession of overlying and conformable micaceous and other flagstones is equally clear until we reach the edge of the true Old Red Sandstone of the east coast, the conglomerate base of which is formed out of the debris of all the rocks hitherto adverted to.

If, however, the line of section be deflected from the Oikel a little to the N.E. towards Lairg and the south-eastern end of Loch Shin, then, the overlying flagstone and micaceous series being intruded upon by vast masses of granite of posterior date, the depository beds are so altered, veined, and fractured as to be made to resemble in some respects the old gneiss of the west coast. But these are local exceptions; for the observer has only to remove to a little distance from the edge of the eruptive granite, to the S.E., and he again finds himself in the same flaggy micaceous series as before,—all the beds dipping to the S.E. and E.S.E. The amount of metamorphism produced upon these micaceous and quartzose flagstones, when they have been most affected, is nowhere better exemplified than where they wrap round the granitic and felspathic rocks of the Ord of Caithness and the adjacent tracts, and where many beds constitute a sort of gneiss, and others form, as before said, the completely metamorphosed and crystalline quartz-rock of the Scarabin Hills (p. 384).

Unwilling to generalize too far upon this point (for I have already said that there may be many tracts where the oldest gneiss rises to the surface), I may, however, express my present belief that these micaceous flagstones (often used indeed as roofing-slates, though none of them are affected by a true slaty cleavage), which constitute the edge of the so-called primary rocks of Ross-shire, and thence range into Inverness, Nairn, Moray, and Banff, are parts of a series younger than the fossiliferous Lower Silurian rocks of the west of Sutherland.

If it be objected that the great thickness of these masses offer difficulties in the way of recognizing them to be equivalents of Silurian rocks, I would reply that we have by no means proved that all such beds are to be considered as successive, since the micaceous flags may have been deposits in the same sea, but at some distance from the bottom rocks; and though apparently overlying them, may have been of almost contemporaneous formation, their subsequent elevation and crystallization giving to them the appearance of a distinct superposition.

Then, again, there may be many curvatures, breaks, and repetitions which I was unable to observe. One considerable fold I did indeed notice in the heart of Ross-shire, in the mountain of Aigean on Loch Faunich, where thinly laminated beds of hard grey quartzose gneiss have a reversed dip to the W.N.W., whilst the country to the east around Loch Luichart is much faulted and broken up.

But, whilst I adhere to the belief that the great mass of the micaceous flag-like and younger gneissose rocks, which succeed on the east, are of more recent age than the quartz-rocks and fossiliferous limestones of the north-west of Sutherland, I repeat that the genuine old gneiss may be brought to the surface in many places in the interior, and even on the east coast, in parts of Banff and Aberdeen. Such points may be left for future labourers to determine. In the mean time I believe that the so-called gneiss of the Sutors of Cromarty, and the rocks extending southwards to Flowerburn, Kincordy, and Rosemarkie near Fortrose, on the east coast of Ross, are simply members of a flagstone series which has been much altered by the intrusion of huge granitic and felspathic veinstones. Fine examples of the conversion of these rocks, in various states of change from an earthy flagstone and shale into a crystalline gneiss, are seen in the cuttings of the new high road which descends from the Old Red Sandstone of the Black Isle down to Rosemarkie, whilst the eruptive rock of compact felspar protrudes in deep-red bosses on the shore at Kincordy and rises into the altered and gneissose hill of Larny to the south of Ethie. The same eruptive felspathic rock, similar to one at Helmsdale, which passes into the granite of the Ord of Caithness, occupies a wooded coast-ridge between Fortrose and Avoch, and throws off the Old Red Sandstone, at a high angle, towards the interior of the Black Isle.

It is obvious, therefore, that the former mineralogical classification of rocks, whereby all these strata, of such very different ages, were merged with the same family as the Old Gneiss which lies beneath vast thicknesses of rocks now known to be of Cambrian and Silurian age, has been highly detrimental to the progress of sound geological science.

The Crystalline Stratified Rocks of other parts of the Highlands compared with those of Sutherland.—It is not in my power to describe in detail the relations of all the stratified crystalline rocks of the Highlands, though I have traversed their chief masses on many parallels. I presume, however, that the same order of succession as in Sutherland may be applied to the stratified crystalline rocks in the west of Ross-shire and Inverness-shire, which occupy the same place in the general series. Thus, when we extend our examination southwards from Sutherland and Ross on the west coast, we find, on entering into any of the numerous bays or marine lochs which indent the coast from Loch Broom to Loch Duich, which is on the edge of Inverness-shire, that quartzose, micaceous, and chloritic rocks, with limestones in their lower members, are successively exhibited,—the whole having a dominant strike from N.N.W. to E.S.E., and all having a prevalent inclination to the E.S.E.

Professor Nicol has already shown how, in many places, such rocks

overlie the older conglomerates and sandstones, which I consider to be of Cambrian age. The only marked distinctive change in the mineral character of these stratified rocks as they range southwards is, that the quartzose or purely siliceous character is not so dominant as in Sutherland and the north-western parts of Ross-shire, the arid, bare, whitened surface of the weathered quartz-rock being no longer dominant. Thus, in the headlands between Loch Kishorn and Loch Carron, the range of bedded limestone is seen, just as in Assynt and Durness, to possess the same joints and oblique rude cleavage, whilst the conformably overlying series consists of a variety of quartzose and chloritic beds, some of pinkish, others of grey colours, and some containing mica and asbestos,—the whole being clearly overlaid by a clay-slate, which ranges down to the shore of Loch Carron.

If we make our observations in a more southern parallel, and pass across Ross-shire from Lochalsh and Kintail on the west to the Old Red Sandstone frontier on the east, the general succession is the same, though there are considerable changes of lithological character when the same rocks are followed southwards or S.S.W. upon their strike. On the south side of Loch Duich, which affords an excellent transverse section, some of the calcareous bands of highly crystalline limestone are white, whilst others are chloritic and greenish and much resemble the Connemara marble of Ireland,—such bands being finely intercalated either in micaceous flagstones in parts calcareous, or in finely laminated slaty flagstones which pass into a rock which must be called gneiss, as it has layers of quartz, felspar, and some mica. Points of syenite protrude here and there, and diversify the projecting rocky bosses. Now, although the prevalent dip of all the strata near Totig is to the E.S.E., we see, in ascending to Inverinat, great flexures, by which the strata, curved at high angles, give their exquisitely beautiful and conical outlines to the mountains in which Loch Duich is embosomed.

At the head of Loch Duich, however, near Inverinat, the dip to the E.S.E. is resumed, at an angle of about 25°, which angle increases to 50°, 60°, and 70° as you proceed eastward through the lofty and rugged defile called the Bealloch of Kintail. There the peaks which form the steep watershed of the north-west of Scotland (in a part of which the splendid Falls of Glomach occur, where the water cascades over a lofty precipice, and not distant more than three or four miles from the salt-water bays) are composed of the same flag-like pinkish quartzose gneiss, the beds of which are seen to be finally thrown off to the E.S.E., thus clearly overlying the limestone and other masses which occupy the shores of Loch Duich.

In pursuing the mountain-track through the Bealloch of Kintail to the head of Loch Affric, I found that, in descending on the long sloping moorlands by which the waters glide away to the east, the stratified masses become more horizontal, with occasional undulations,—so that very much the same class of quartzose rocks is continued very far eastwards, their bare stony summits constituting the favourite resort of ptarmigan, their slopes the haunt of deer, and their valleys the breeding-grounds of grouse. The undulations of

such rocks are well exposed where the principal feede of Loch Affric escapes from the higher moorlands into that fine sheet of fresh water from the highlands of Kintail, and at a pass and ford called "Aa na Mullich *."

I further believe that the regularly-bedded limestones, which are intercalated in the chloritic and quartzose rocks of Dumbartonshire, and are seen on both banks of Loch Fyne, and also in terraces to the north and west of Inverary, may be classed with some of the oldest of those stratified masses which, like the limestones of Sutherland, are unquestionably of Lower Silurian age. For these calcareous bands also pass under vast masses of mica-schist and quartzose-gneissic rocks. Moreover, as one who has explored the wilds of the Breadalbane deer-forests, I think that the vast expanses of quartziferous flagstones, mica-schists, &c., are simply the prolongations of those rocks of the North-western Highlands, which have here been treated of. Undulating at slight angles of inclination through Glen Orchy, and clasping round the granite of Ben Cruachan on the one hand, or pierced by the porphyries of Glencoe on the other, these flag-like strata, occasionally passing upwards into clay-slate, extend to the S.E. in broad curves, over the region of the Moor of Rannoch, and around the Black Mount; whilst along the banks of Loch Tay they contain regularly-bedded limestones, which in their turn dip to the S.E. under other schistose rocks.

In following them to their south-eastern frontier in Dumbartonshire, where these rocks, terminating upwards in clay-slates, are surmounted by the Old Red conglomerate and sandstone, we may indeed speculate upon the unfolding in such tracts of the equivalents of younger and higher strata than any which are observed in the northern counties. Thus, the chloritic schists of Ben Lomond, containing pebble-beds which underlie the clay-slates, may prove to be the equivalents of some of the Silurian conglomerates of the S.W. coast of Scotland. Let us hope that the day may come when fossils will be discovered in some of those regularly-stratified masses of such varied lithological composition, and thus enable us to speak of their age with the same decision which has been applied to the crystalline strata of the west of Sutherland.

Looking at the Highlands as a whole, it is essential to observe that, in proceeding from north to south, the geologist meets with vastly larger masses of intrusive rock than in the typical tract of Sutherland. Thus, the edges of the huge granitic Grampians, alone,

* I hope that my Highland pride may be pardoned if I attach great interest to this gorge, seeing that my ancestor Colonel Donald Murchison (whose brother, my great grandfather, was killed at the battle of Sheriff Muir) selected it as the spot where, in the year 1716, he so placed the native Highlanders under his command, all of them Jacobites, as well as their chief, the exiled William Earl of Seaforth, whose lands he was defending, that he successfully resisted and beat back the troops of George I., who in vain endeavoured to take possession of Kintail; and hence these mountains were held for their noble owner, who was eventually pardoned. I live in the hope that my eminent friend Sir Edwin Landseer will soon fulfil his promise, and gratify me by producing a painting of this scene, the history of which is well known to all old Ross-shire Highlanders.

call for a separate historian, who shall describe the nature, and, if possible, fix the age, of all the successive coats of the older crystalline rocks which are folded around that vast igneous nucleus, just as Colonel Imrie did in reference to one transverse gorge, which he laid open so admirably forty years ago. We have yet to ascertain the exact relations of the uppermost clay-slate of Forfarshire to the overlying Arbroath flagstone, which must be considered the base of the Old Red Sandstone of that tract. With the expansion of the older stratified crystalline rocks as they fold over to the S.E., it must be borne in mind that there are numerous centres of eruption, such as that, for example, of Ben Cruachan, in Argyllshire, and other mountains to the south and east of it, which penetrate and throw off the stratified masses into various undulations. Other anticlinals and synclinals occur without any such apparent motive cause, as in the clear and unambiguous section of Loch Eck, in Argyllshire, to which I formerly called attention*, and where a vast mass of gneissose mica-schist is seen to rise from beneath the chloritic schists and limestones of Loch Fyne. When the geological surveyors shall be provided with accurate maps, I trust that all these stratified masses of the crystalline rocks of the Highlands will have their true relative places assigned them. In the mean time much may be done, not only in the endeavour to rival Mr. Peach in detecting fossils, but also in the effort to coordinate the fractures which these stratified masses have undergone, and to read off the periods when numerous fissures were made,—the one set longitudinally, or along the strike of the beds as seen in Loch Ness and the line of lakes of the Caledonian Canal—the other transverse, or across the strata, of which the North-western Highlands offer many striking examples, to some of which allusion has already been made.

I cannot attempt to describe all the lithological variations in the rocks which I believe to be the geological equivalents of the crystalline rocks of the N.W. Highlands, in the counties of Aberdeen, Banff, &c. From what I saw, however, in former years, of the thin micaceous flag-stones and clay-slates, &c. of those tracts, I have little doubt that they belong to the same series as that now under consideration. The granitic mountain of Ben na Chie, which I then examined, seemed to me to have performed precisely the same eruptive part in the east as Ben Cruachan in the west, perforating stratified sedimentary rocks, and producing much alteration in them near the points of contact.

The general view of the succession here offered must, however, be alone tested by traversing the northernmost counties from N.W. to S.E., and by marking the manner in which one group succeeds the other. In such examinations, a great number of dislocations like that which has been noticed in Suilven of Assynt, and numerous anticlinals and synclinals, with outbursts of igneous rocks, will doubtless be detected, by which, and by parallel upheavals, the same set of beds will be found to have been frequently repeated between the two coasts.

* Quart. Journ. Geol. Soc. vol. vii. p. 169.

The great physical fact, however, in respect to the series of crystalline rocks in Sutherland, is, that their *lower* members contain those limestones in which organic remains have been found, and that large masses of chloritic, micaceous, and gneissic flagstones, clay-slates, and schists are so superposed, that little doubt can remain that they are also of Silurian age. Allowing for many undulations and repetitions, I see no reason for believing that those overlying crystalline masses are of much greater thickness than the Lower Silurian rocks of Wales and the adjacent English counties.

Having no evidence of the existence of other fossil remains which should indicate the presence of Upper Silurian rocks, and seeing how poorly such strata are developed even in that part of the south of Scotland (Ayrshire) where the Lower Silurians are so rich in fossils, my inference is that the younger members of the Silurian system have never been deposited in the far north. There, a great upheaval of the Lower Silurian, or the quartzo-gneissose series in question, separates it sharply from the Old Red Sandstone, which overlaps it in entire unconformity,—this great break accounting for the nonexistence of any representatives of the Upper Silurian rocks.

It is unnecessary that I should continue to combat, as I did at the last Glasgow Meeting of the British Association, the theoretical idea that the varying and alternating mineral layers of the rocks I have been describing are lines of cleavage or lamination as distinguished from true stratification; since that view can, I presume, no longer have any supporters. In considering these rocks as regularly stratified deposits of different mineral matters, I simply adopted the opinion of all my eminent precursors since the days when Hall and Playfair classed them as metamorphosed sediments. Not only have we examples of coarse grits and sandstones throughout them, but even when we follow them to the south we find regular beds of pebbles intercalated in such chloritic and micaceous schists. In short, they present all the signs by which truly stratified aqueous deposits are defined, not only in their successive mineral layers, but also in having wavy bands of schist interpolated among sandy beds, and the whole being affected by symmetrical joints.

The presence of organic remains was alone wanting to complete the natural inference which I suggested in 1854, that many of the stratified crystalline rocks of the Highlands are simply the metamorphosed equivalents of the Lower Silurian rocks of the south of Scotland.

Crystalline Rocks of the Shetland Isles.—My voyage from point to point of the Shetland Islands was much too rapid to enable me to connect all their different rock-masses with those of the mainland. I may, however, suggest that some of the northernmost crystalline stratified masses of Unst, extending out to the small islet called the Muckle Flugga, on which the most northern lighthouse is built, most probably belong on the whole to the younger gneiss and flagstone series.

There may, however, exist, on the western shores of the mainland (which I did not visit), some representatives of the older gneiss.

The most remarkable exhibition of the flaglike gneiss with a persistent and uniform dip is seen on the western cliffs of the island of Unst, where the strata, in precipitous cliffs 200 to 300 feet high, succeed each other rapidly at angles of about 45°. In the Burra Fiord of the same island, granite prevails in strong veinstones, as also in the islets called the Burra Fiord Holms. It is on the outermost of these bosses of barren gneiss that the new lighthouse was erected during the recent Russian War; the summit of the rock is 230 feet above the sea, and exposed to the lashings of the wild Northern Ocean. This rock (named the Muckle Flugga, to distinguish it from a more southern boss, the Little Flugga), with the exception of a small rock called the Out Stack, is the northernmost point of land in Her Majesty's dominions, and certainly the most northern inhabited spot; it is very nearly on the 61° of N. lat.

The rock, up the steep face of which 250 steps are cut, by which we ascended to the lighthouse, consists of sharply inclined shelving masses of gneissose, micaceous, and quartzose flagstones, with some garnets: it is penetrated by many veins of granite. The strata, like those of Unst, dip E.S.E. about 45°, and are all perfectly parallel,—a circumstance the more to be wondered at when it is seen that from Somburgh Head on the extreme south to the Muckle Flugga on the extreme north of the whole group, the prevalent strike and dip are preserved for a distance of eighty miles.

In Balta Sound a visit was made to the mines of chromate of iron, much opened out and extended of late years. This mineral occurs in serpentine rocks with bosses of pure greenstone. Following up certain veinstones on the surface from the north side of the Fiord between Swenee Ness and Buness, the mineral has been found to expand into a large stockwork, about one mile from the shore: the chief direction of the mineral mass is from W.S.W. to E.N.E. There the rock is cut into to a depth of about 86 feet, without detecting any deterioration or diminution of the chromate in the floor of the quarry, which is from forty to fifty feet wide. This mineral mass hades to the north at an angle of from 70° to 80°, and is situated on the hill called Keen Hill, and at the foot of the higher rocky hills called Heysags, which stand out so boldly, overlooking Haroldswick Bay.

The other tract where I had an opportunity of studying the crystalline rocks, was at the Out Skerries of Whalsey, that very singular group of low, rugged islets, chiefly composed of gneiss with granite-veins, but containing one strong band of limestone. It is on the most eastern of these rocks, or the Bound Skerry, that a new lighthouse has been just erected, to exceed in power that of the adjacent Gruna Light*.

Mr. Stevenson here called my attention to the manifest proofs of

* After passing the afternoon upon the rocks, or in admiring the new mechanical contrivances in the lanterns of the lighthouse, we steamed out to the north about ten miles in the dark, to test the effect of one of the improvements made by our companion, Mr. Stevenson, when it was perceptible to all of us that the new light was very superior to the old one on the adjacent rock of Gruna, in the grander and more pyramidal flashes which it gave out.

the remarkable power of the sea-waves when lashing upon this exposed spot in great storms.

The seaward or north-eastern face of these gneissose rocks sloping upwards presents the most chaotic aspect, being covered with clusters of large angular blocks—one of the largest of these being perched at nearly seventy feet above the sea. Now all of them have been torn out of their beds, and most of them moved up-hill for a considerable number of feet, to within a few yards of the base of the new lighthouse. For my own part, I was at first incredulous as to the mode of producing what my lamented friend Leopold von Buch would have called a true "Felsen Meer;" but when Mr. Stevenson brought the data before me, it was quite evident that the sea had done it all. Thus, an inhabitant pointed out some of the chief blocks, several of them of many tons weight, which in a great storm some years back had been moved upwards on the incline fifteen to twenty feet, to heights of fifty feet above the sea. These in their upward translation had scored the rocks over which they passed, just as the stones held in a glacier groove and scratch in their descent; and the freshness of the markings was quite striking. Not trusting to histories of the past, and for a moment doubting even the clear evidence offered by the scoring of the rugged subjacent rock, I interrogated an intelligent under-officer of the lighthouse, who had been two years on the spot, and ascertained that even in the preceding winter, and when the new lighthouse was in course of construction, a huge mass of stone near the sea-level, of which he showed the very bed out of which it had been lifted, had been wrenched out of it and moved up an incline of 10° or 12° to a distance of sixteen feet!—and with this proof all scepticism vanished.

Lastly, perceiving a singular cavernous chasm into which the waves hurl up fragments of rock varying from a few inches to two yards in width to a height of fifty or sixty feet above the sea, I found that, being there confined as in a gullet, they are continually agitated and rolled about in every great storm until most of them are as much *rounded* and water-worn as if they were part of an ordinary sea-beach, before they are shot out to the other side of the chasm.

Old Red Sandstone of the North-east of Scotland.—Let us now take a rapid review of the character, dimensions, and fossil contents of the Old Red Sandstone of the North-eastern parts of Scotland, where in the year 1827 the separate masses were described by Sedgwick and myself as offering the fullest and best types of a series which we have since shown to constitute a natural group, the equivalent of the Devonian rocks of other countries. This review is the more called for now that we know the precise geological relations of the base of the Old Red Sandstone of England to the Upper Silurian rocks on which it rests. It is also necessary to point out some features in the successive distribution of its animal remains in the latter tracts and in the central counties of Scotland, when compared with that northern development to which attention is now particularly directed, and to show that the ichthyolitic flags of

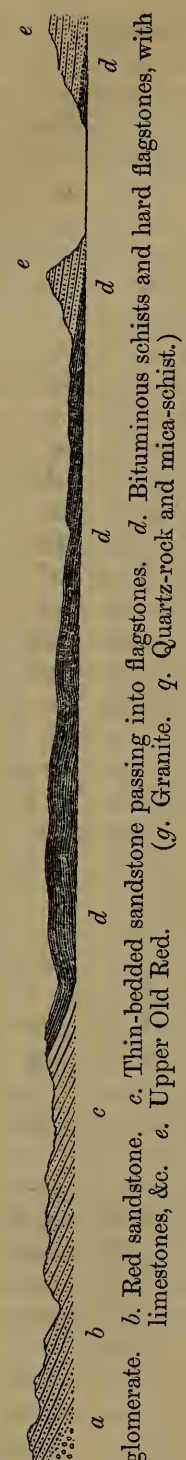


Fig. 9.—*General Section of the Old Red Sandstone of the North-east of Scotland.* (From 'Siluria,' new edit. p. 280.)

a. Old Red conglomerate. *b*. Red sandstone. *c*. Thin-bedded sandstone passing into flagstones. *d*. Bituminous schists and hard flagstones, with limestones, &c. *e*. Upper Old Red. (*g*. Granite. *q*. Quartz-rock and mica-schist.)

Caithness are not the lower members of the Old Red Series, as previously stated in geological works.

The Old Red Sandstone, in the extended sense of the term, is not what some geologists, who have never examined the North-east of Scotland and the Orkney Islands, have considered it, a small and unimportant formation, the upper part of which might be classed with the Carboniferous deposits, and the rest as of no greater importance as to the time occupied in its formation than a mere fragment of the Devonian group only. On the contrary, the Old Red group of this northern region is a grand and expanded series of very diversified mineral character, which, both from dimensions and organic remains, must be considered a full and adequate equivalent of all the Devonian rocks of South Britain, Germany, Russia, France, Spain, and Turkey. The group as seen in Caithness and the Orkney Islands is composed of three parts—

1. Lower red conglomerate and sandstones.
2. Grey and dark-coloured flagstones and schists, in parts both bituminous and calcareous.
3. Upper red and yellow sandstones.

The annexed general section (fig. 9) exhibits this order.

Lower Old Red.—The lower red conglomerate and sandstone (*a*, *b*, *c*) form the external and unconformable eastern fringe of all the stratified crystalline rocks which have been described. Whether the latter consist of quartzose gneiss at Strathy Head on the north shore, or be followed inland along an irregular boundary by Ben Ghream until they become the thin-bedded quartz-rocks of the Scarabin Hills, or consist of granite at the Ord of Caithness, or of gneissose micaceous schists as they range from Sutherland into Ross-shire and there occupy the heights of Wyvis or fold round the lower country of Easter Ross by Dingwall, Brahan Castle, and Fairburn Tower, until they enter Inverness-shire above Beauley, we see everywhere similar rock-relations. Throughout all this tortuous line, the lowest member of the great group under consideration is compounded out of the con-

tiguous and subjacent rocks,—the derivative beds having always a strike and dip different from those of their parent crystalline rocks; any approach to an agreement in their relations being local and accidental. Allusion has already been made to the great change observable in the outline and aspect of the country when we pass from the one to the other group of rocks; and it is useless to enumerate the numberless cases which have fallen under my own observation, where the younger deposit overlies in slightly inclined layers the highly inclined crystalline strata, which, together with an occasional boss of granite or syenite, have invariably afforded the materials out of which the Old Red strata have been composed.

Describing some striking examples of the lower conglomerate, we shall see how it passes up gradually into the Caithness Flagstones.

On the east coast of Caithness, inclined both to the west and east, the Old Red conglomerate and sandstone clasp round the quartz-rocks of the Scarabin Hills. When adjacent to the quartz-rock, the Old Red conglomerate abounds in its fragments; but on the east and south of Braemore, granite and gneiss are added to the débris. I ascertained, by passing along the summits of the rugged Scarabin Hills, that the Old Red conglomerate is there almost entirely compounded out of the white quartz-rock on which it rests *.

This feature is remarkably well seen on the western slope of the Scarabins, where the white brecciated conglomerate, in twisted sheets, dips off the various shoulders of the quartz mountain, to the W.S.W. and N.W. Other conglomerates, whether capping the detached and lofty Morven, or its peaked and low satellites, the Maiden Pap and the Schmian, being further removed from the pure quartz, are more or less red, and were described by Professor Sedgwick and myself thirty-one years ago, when we ascended the Schmian †.

In descending the River of Langwell, the usual conglomerate is seen to be equally local; for there, whether it rests upon the newer gneiss and grey-coloured flagstones, or on the associated and eruptive granitic rocks which range from the Ord and across Ousedale, it is found to be of a prevailing red colour, chiefly due to the prevailing quantity of granitic fragments. In further descending the stream from these bosses of conglomerate to the bridge under the House of Langwell, a grand succession of thin-bedded deep-red sandstone is exhibited, which, dipping to the E. and E.N.E., cannot have less than a thickness of 800 or 1000 feet.

Now, all this thin-bedded sandstone (fig. 9, *b*, *c*), which passes under and graduates upwards into the series of Caithness flagstones, did not afford to the patient search of Mr. Peach the trace of a fish, any more than it did to my former endeavours. It is this great lower member of conglomerate and thin-bedded sandstone, which I have no hesitation in considering to be the representative in time of the

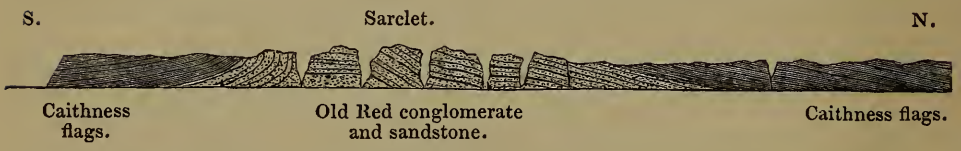
* I made this last examination from the hospitable mansion of the Right Honourable the Speaker and Lady Charlotte Denison, in September 1858. The Scarabin is probably derived from the Gaelic word *Skearach* (rough), and *ben* or *bein* (hill).

† See Trans. Geol. Soc. 2nd ser. vol. iii. p. 138.

Cephalaspis-zone of Shropshire and Herefordshire in England, and of Forfar and Perth in Scotland.

I examined the partial uprise of these lower beds through the Caithness flags at Sarclet, four miles south of Wick,—a point to which my attention was called by Mr. Peach. When seen from the sea, as represented in fig. 10, it is manifest that the lower rocks have

Fig. 10.—*Section of the Lower and Middle Members of the Old Red Sandstone at Sarclet, near Wick.*

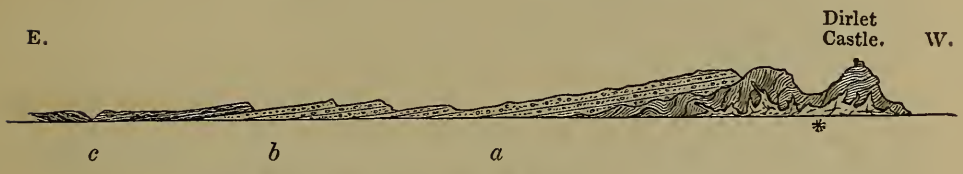


been protruded by great force, which has subjected the whole of the flanking series of flagstones to extensive transverse breaks and fractures, which, on examining the shore, are found to exist with partial reversals of dip. The little thriving fishing-station of Sarclet is one of those numerous indentations of the coast of Caithness which the stormy eastern ocean has helped to open out, but which, like many of the other coast-clefts which I have seen, is mainly due to an original powerful dislocation, resulting in transverse gullies which the sea has simply widened or deepened. Here the breccia or conglomerate, as at the Ord of Caithness, is made up chiefly of granite and quartz-rock, both grey and white: the imbedded fragments, from the size of a bullet to that of a man's head, are sometimes angular, but often rounded as if they had undergone shore-action. Piled up in massive beds of from 15 to 20 feet each, which alternate with deep-red shaly layers, this conglomerate, where I examined it (for it folds over in a very broken arch), dips to the north, and passes under strong-bedded, hard, fine-grained micaceous grit, freckled with marks of iron-ore, which in its turn is covered with thinner beds distinguished by their rippled surface. This upcast broken mass is seen to be covered by the flagstones, which, as we ascend in the series, whether by going towards Wick on the north or to the Yarrow Hills and to Latheron on the west and south, become fossiliferous and constitute the bituminous flagstone group. It is worthy of remark, that even some of the lower red grits and sandstones effervesce with acids, like many portions of the overlying Caithness flags.

Another spot where the older conglomerate and sandstone have been protruded through the broken undulations of the Caithness flags, is at Dirlet Castle, in the interior of the county, and about twelve miles W.S.W. of Thurso, to which Mr. Peach and myself were directed by that zealous and able explorer of rocks and fossils, as well as of living plants, Mr. Robert Dick (see fig. 11). There a boss of flag-like gneiss (probably the newer gneiss, but largely affected by intrusion and pierced by granite), which is covered by the ruins of the old castle, stands out of the middle of the Thurso Water. This crystalline rock, dipping sharply to the E.S.E., is surmounted, as shown in this diagram, by a coarse conglomerate, almost a breccia, which

inclines to the N.E. at about 10°, and soon graduates up into purplish and grey siliceous and micaceous thin-bedded sandstones, covered by the true dark-grey (in parts almost bluish) flagstones, which, after curvatures (doubtless accompanied by breaks which are hidden by moss), become highly fossiliferous in the adjacent hills of Bannis-kirk, &c.

Fig. 11.—*Section showing the Relations of the Lower Members of the Old Red Series near Dirlet Castle.*



* Gneissic and flaggy schists, penetrated by granite. *a*. Granitic conglomerate, or lowest member of the Old Red Series. *b*. Sandstone. *c*. Caithness flagstones.

In following the Old Red conglomerate southwards along the eastern part of Sutherland, where it forms the inland boundary of the coast-range of the Oolitic beds of Helmsdale, Clyne, and Brora, which it separates from the crystalline rocks, the mass may much more truly be called a breccia; for here the included fragments, which are lodged in a paste of pink-coloured or granitic sand, are micaceous fragments of all the varieties of the quartz-rock series, viz. hard, micaceous, finely laminated sandstones of various colours passing on the one hand into gneiss, and on the other into pure quartz-rock.

On the south flanks of Wyvis, the loftiest mountain of Ross-shire, the gneissose flagstones are truncated, and flanked by enormous masses of conglomerate and sandstone, in which are deep rents wherein the streams descend to the Bay of Cromarty. One of the most remarkable of these gorges is watered by the Alt Grant, the massive conglomerate precipices on the sides of which have been described by Sedgwick and myself*; another is that in which the Alness River flows. In ascending that stream above the House of Ardross, the formation is perceived to assume an aspect differing a good deal from its usual appearance. In their upper parts the beds are of dark-grey, greenish, and deep-red soft shale, either highly inclined or in rapid undulations, and in the lower part of a very coarse conglomerate and a reddish and yellowish, gritty, thin-bedded sandstone. The lower portion of the conglomerate is here not only vertical and much twisted, but is also much mineralized and contains a thick vein of rich hematitic iron-ore. All these lower beds of the Old Red have been deposited quite athwart the edges of the quartzose flagstones and mica-schist of Wyvis and its adjacent mountains, which have the usual dominant strike of N.N.E. or N.E. and S.W., whilst the conglomerate and sandstone of this tract strike nearly east and west, and dip southerly at angles decreasing as you recede from the mountains.

Allusion was formerly made to the bold forms which the Old Red

* Trans. Geol. Soc. Lond. 2nd ser. vol. iii. p. 147.

conglomerate assumes in various hills where it rises in more or less rounded pyramidal masses, which have been embossed as it were on the edges of the crystalline rocks. Good examples of this are given in the fly-flap of the coloured section given by Sedgwick and myself, where the Maiden Pap and Morven rise above the adjacent quartz-rocks, and again where the hill of Meal Turach stands out in Ross-shire above the gneissose rocks of Loch Glas, at the foot of Wyvis*. The hill of Ben-a-vraggie, above Dunrobin in Sutherlandshire, on which the monument of the late Duke of Sutherland stands, is also a striking example of these lower conglomerates.

At Skibo Castle, the seat of my friend Mr. Dempster, a deep-red coloured sandstone has been opened out in the lower division of the formation, the strata of which dip away from the slopes of gneissose hills to the Dornoch Firth; and in this sandstone Miss Dempster procured two incurvated casts about 8 or 9 inches long, which, terminating in points, rudely resemble the pincers of a huge Crustacean. If these casts should prove to be referable to some such creature as the *Pterygotus* of Herefordshire, Shropshire, Forfarshire, &c., they stand as yet alone as indications of animal life in the Lower Old Red of the North-east of Scotland.

In this vicinity and in the much higher beds which shelve away on the coast near Embo with an easterly dip, the sandstones become more yellow, and range along the shore to the town of Dornoch. Near Embo they contain strong pebbly beds, and are marked by blotches of deep-red shale, occasionally circular. In these same beds and among the pebbles which have been chiefly derived from the crystalline rocks of the interior, Mr. Peach and myself detected some fragments of those cherty and very peculiar beds of the Durness and Assynt limestone, as well as portions of quartz-rock. In following these upper ledges from Embo to Dornoch, the rock is well exposed in quarries which have been opened for the construction of the new buildings in the town; and the yellow and even whitish-coloured sandstone there predominates over the deep-red, the latter being thrown away as refuse. Now, as these light-yellow strata with occasional pebbly beds are inclined gently to the S.S.E., they (as well as the sandstones of Tain and Tarbet Ness) seem to form the north-western side of a wide basin, the south-eastern side of which reappears on the opposite side of the Moray Firth, near Elgin, where similar yellow sandstones occur.

In Ross-shire, the quartzose micaceous schists and gneiss through which the Rivers Connan and Orron flow from the central highlands and the mountains of Strath Connan and Strath-glas, have the prevalent dip to the E.S.E., and are admirably exposed on the banks of both those rivers, just where they issue to the low tract of Easter Ross. At no spot is the unconformity between these crystalline rocks and the Old Red Sandstone better seen than to the west of the ancient Tower of Fairburn†, where a feeder of the Orron flows over

* Trans. Geol. Soc. Lond. 2nd ser. vol. iii. pl. 14. figs. 3 & 5.

† The seat of the Mackenzies of Fairburn, my maternal ancestors, who possessed the estates of Fairburn, Strath Connan, and Monar.

mica-schist inclined to the E.S.E. at 70°, the edges of which are covered by a coarse red conglomerate, which in descending to the low country in the same direction, but at much lower angles, is beautifully displayed on the banks of the Orron,—the river cascading over beds of pebbly conglomerate and intercalated hard sandstone, and the whole subsiding under the red sandstone of the Black Isle. In like manner when we pass to the south side of the Beauley River we find the crystalline rocks of Strath-glas similarly flanked by the Old Red conglomerate and sandstone, which, ranging from W.S.W. to E.N.E. along the south side of the Murray Frith, repose on the crystalline rocks and dip to the N.N.W.

We thus learn that the Old Red conglomerate and sandstone are everywhere thrown off from the broken and protruding edges of the older rocks, and that the direction and indication of these regenerated deposits vary with each great promontory.

But besides these main base-lines, there are other and minor ridges of elevation, by which, whether by the rise of granite or granitic gneiss, the conglomerate and bottom rock of the Old Red are exhibited. Such, for example, is the uprise of the granitic and felspathic rocks, with metamorphosed strata, in parts a true gneiss, at the mouth of Cromarty Bay. There, however, the conglomerate is feebly exhibited only; but by following the same line of elevation along the East Coast, other gneissose and granitic rocks (evidently metamorphic and eruptive) protrude into the altered rocks, extend to Fortrose and Avoch, whence to Kessock Ferry House, opposite Inverness, there is a most instructive development of the conglomerate and sandstone. Of this sandstone there are fine quarries at Avoch, the beds being in highly inclined positions, dipping away from the eruptive rocks of Craig Wood.

Nowhere in Ross-shire is the conglomerate better displayed than on the coast extending from the south of the Bay of Munlochy by Kilmuir to Drynie, and in the cliffs between that place and Kessock Ferry opposite Inverness. Whether in the headland called Craigie How, in which a large natural cave is opened out upon the inclined plane of the beds, or in adjacent spots where freestone is intercalated, the strata are seen to dip inland, or from 50° to 70° and 80° to the W. and W.N.W. Hence we see how, along this coast-line of elevation, the red sandstone of Redcastle, Taradale, and other places in the Black Isle where the red sandstone is quarried, is in alternation with conglomerates which here and there rest upon crystalline rocks.

The traveller who reaches Inverness from the South, and has a short time only at his disposal, will indeed do well to cross the Kessock Ferry, where, keeping to the sea-shore and passing by Craigton to Drynie, he may examine many remarkable masses of the conglomerate with irregular courses of hard, finely laminated, quartzose sandstone, so made up of granitic detritus that they often look like granite-veins traversing the conglomerate. The latter is there compounded out of various granites (including those which abound on the shores of Loch Ness), of red porphyry, and of much quartz-rock, whether grey, white, or brown; whilst fragments of

mica-schist and gneiss are the smallest and least abundant materials. The largest boulders in this coarse conglomerate are about four feet in length, and, differing from those of the breccia of the east of Sutherland, they are all rounded. The dip of all these beds is also 70° to the W.N.W., or sharply inland, thus seeming to throw the Old Red Sandstone of the Black Isle into a trough.

Succeeding to these coarser conglomerates, but alternating with pebble-beds, are the chief freestones of the group, which are so extensively used for building-purposes throughout the counties of Ross, Cromarty, Inverness, Nairn, Moray, &c. This sandstone, of which quarries are opened in numberless localities, is of very varied tints of red, is occasionally much variegated either by greenish and whitish spots of earthier matter (Thon-Gallen of the Germans), or by a regularly ribboned or striped structure of thin layers of deep red alternating into lighter and yellowish laminæ of deposit. In short, we find in the rock those lithological features, which in the early days of geology were erroneously supposed to be characteristic of the New Red Sandstone only, but which are now known to be prevalent not only in the Old Red, but also in the red and variegated Lower Silurian or Caradoc freestones of Shropshire. In the lower conglomerate and sandstone, as well as in the overlying gritty and pebbly beds with fine building-stones, organic remains have as yet been very sparingly found—a scale or two of a fossil fish being all that I have heard of; and whether it be on the coast of Cromarty, or at Strathpeffer in the interior of Ross-shire, it is only when we reach certain schistose beds, often more or less bituminous (the equivalents of the Caithness Flags), that fossil fishes begin to be distinctly recognized.

No identifiable organic remains have as yet been detected in the lower sandstones and conglomerates of this series in the North of Scotland; yet these thick and finely levigated masses are considered by me to represent in time the lowest beds of the Old Red of Forfarshire, Shropshire, and Herefordshire, which contain *Pterygotus*, *Cephalaspis* and *Parka decipiens*—remains which are quite distinct from those of the bituminous schists and flagstones of Caithness.

Caithness Flags, or *Middle Division of the Old Red Sandstone of the N.E. of Scotland and the Orkney Islands* (*d* of the section, fig. 9, p. 394).—Having indicated in the General Section, fig. 9, and in figs. 10 and 11, that the Lower Old Red Sandstone and Conglomerate pass up gradually into the Caithness Flags, it is manifest that the latter can no longer be ranked, as they have been, with the lower member of the group,—the more so as I have shown that the ichthyolites they contain are in other parts of the world associated with shells which characterize the middle and upper divisions of the Devonian rocks*. In no part of the British Isles are these flagstones so copiously elaborated, and so rich in fossil fishes, as in Caithness and the Orkney Islands. It is unnecessary that I should here present to the reader accounts of the numerous variations in litholo-

* Russia in Europe, vol. i. p. 64; Siluria, new edit. p. 382; and *infra*, p. 414.

gical composition which these rocks assume in different parts of their range, or attempt to describe their numerous undulations as well as the powerful fractures to which they have been subjected. Lithologically described many years ago by Sedgwick and myself, and since then treated of in my own publications*, they have acquired a wide celebrity for their great economical value, whilst they are deeply interesting to the palæontologist as containing those numerous ichthyolites described by Hugh Miller and Agassiz.

The real study of these flagstones is best made upon the coast-cliffs, from the lowest strata near Dunbeath to their central parts at Wick, and thence to the highest beds on the shores of the Pentland Firth, where they pass up into the overlying sandstones of Dunnet Head (fig. 9, p. 394). Many of the beds are so bituminous, owing to the quantity of animal matter they contain, that even in 1827 they were described by me as bituminous schists†.

One of the most instructive ascending sections in the environs of Thurso is made (as pointed out to me by Mr. Robert Dick) by proceeding from the gneissose rocks of the Dorrery Hills on the W.S.W. to Thurso and Holborn Head on the E.N.E. In this district the observer proceeds from the crystalline rocks through a vast thickness of superposed strata. The lowest of these, as usual, are breccias and conglomerate, followed by various sandstones in parts calcareous; and then follows the flagstone series, in which Mr. Dick enumerates from 13 to 15 varieties, including sandstones, one variety of which, at the old Bishop's Castle near Thurso, is used as a building-stone. This flagstone series is extended into the various headlands of the north coast, and is prolonged eastwards in broken undulations to Dunnet Head, Duncansby Head, &c. Until a correct map of the county be constructed, it is difficult, if not impossible, so to lay down the range of the strata as to show those parts where the flagstones expand to vast dimensions, and where they are affected by powerful and numerous fractures and faults‡; for, though the outline of the country is on the whole one of gently sloping hills and plains, the fractures to which the strata have been subjected are powerful and numerous. Many of these dislocations are well exhibited in the coast-cliffs; and according to Mr. Robert Dick they are equally abundant inland, and particularly around Loch Watten. Hence it is very difficult to form an estimate of the thickness of the flagstone group. There are, however, tracts (as between Lochs Rangan and Stemster, and again between the Dorrery Hills and Banniskirk) where

* See particularly the last edition of 'Siluria,' in which the Chapter on the "Old Red Sandstone" was printed long before these memoirs were read.

† Trans. Geol. Soc. Lond. 2nd ser. vol. ii. p. 314.

‡ Spreading out a heap of flour upon the board of his bakery, Mr. Robert Dick, who had heard me complaining of the want of any map of Caithness, produced, in a short time, a model, in relief, of the ground and drainage of this county, the geography of which (with the exception of the excellent charts of the coast made by the Admiralty Surveyors) is in a worse state than in any part of Scotland. I blessed the Duke of Sutherland for having had a good map of Sutherland executed, whilst the want of any map of Caithness approaching to accuracy is sorely felt by the exploring geologist.

the persistent inclination of superposed strata (in the last case to the E.N.E.) induces Mr. Dick as well as myself to assign very considerable dimensions to the deposit.

The manager of Mr. Traill's large quarries at Castle Hill (Mr. McBeath) defines sixteen different beds, nearly all of which, to the ordinary eye, present a great sameness of structure. Seeing the indestructible character of this hard pavement-stone, which resists the weather, even when set on edge to form fences, I suggested, when on the spot, that their great tenacity and resistance to the atmosphere were in all probability due to the fine admixture of silica and alumina, in a finely pulverized condition, with certain proportions of carbonate of lime and bitumen (the latter chiefly obtained from the numerous fossil fishes of the deposit), with traces of iron. The analysis of Dr. Hofmann, to whom I submitted four varieties of the flagstone of Castle Hill, taken from the base, middle, and summit of the Castle Hill quarries, has confirmed the view as given in the Table of the accompanying footnote*. Where the

* Table.

Mineral analysed.	Silica and Silicates, insoluble in HCl.	Oxide of Iron and Alumina.	Carbonate of Lime.	Organic matter.	Water, loss at 100°C.	Salts of Magnesia, the Alkalies, &c.	Total.
No. 16. Top flag..	68·40	10·21	10·93	3.88	0·42	6·16	100·00
No. 7. Middle flag	69·45	11·50	10·66	5·79	0·40	2·20	100·00
Bituminous Shale.	69·96	8·15	7·72	10·73	0·53	2·91	100·00
No. 1. Bottom flag	61·39	4·87	21·91	3·40	0·20	8·23	100·00

In analysing a portion of the bituminous schists from the property of the Earl of Caithness (near Barrogill Castle), Dr. Hofmann reported to me as follows:—"When submitted to the action of heat, this substance evolves a considerable amount of gas, and likewise of oily matter containing a certain proportion of ammonia. The residue which remains behind is a greyish mass, consisting essentially of silicate of alumina (clay) mixed with a certain quantity of sesquioxide of iron and of sulphate of lime. A very minute proportion of phosphoric acid was likewise found to be present. The loss which the mineral undergoes on heating was found in two consecutive experiments to be 30·21 and 30·02; so that the mineral may be said to contain, in round numbers,

"Fixed matter (mineral) 70 per cent.; volatile matter (organic) 30 per cent.

"In determining the amount of gas furnished by the distillation of the mineral, a portion of it was heated in an iron tube, in order to imitate, as nearly as possible, the circumstances of an operation on a large scale. In two consecutive experiments which were performed in this manner, 100 grammes furnished in one case 7690 cub. centim., and in another 7430 cub. centim.

"Assuming then 100 grammes of the mineral to yield, on an average, 7500 cubic centimetres of gas, a ton of the material would furnish 2690 cubic feet. The ordinary varieties of coal used in gas-making yield from 8000 to 10,000 cubic feet of gas per ton. The gas obtained from the mineral is very luminous; it is nearly entirely free from sulphur, and it is on this account very readily purified. The residue left in the retort after the expulsion of the gas retains but a small amount of carbon, viz. 8·5 per cent.; this residue has therefore but little value as coke.

"The mineral in question is in no way related to ozokerite, as has been suggested. From that substance it may be at once distinguished by its infusibility (ozokerite fuses at 80° C.=176° Fahr.), and by its entire insolubility in alcohol and ether, in which solvents ozokerite, although with difficulty, dissolves."

quantity of bitumen increases to so great a degree as to exude from cracks and fissures in the stone, the quality of the paving- or floor-stone necessarily diminishes; but when the value of this bitumen is sufficiently known, the flagstones permeated by it may be largely quarried for lighting and other purposes.

Revisiting that portion of the north coast of Sutherland which confines upon Caithness, and which was formerly described by Professor Sedgwick and myself, I found that, whilst the lower part of the Old Red series in the tract extending from Strathy to Reay exhibits in many places (and particularly near Port Skerry) shore-ledges well exposed at low water, of powerful coarse breccia made up of granite, porphyry, and the flaggy gneiss which is penetrated by these rocks, this coarse breccia, including huge angular blocks from 2 to 3 feet in size, is, notwithstanding many breaks, observed to be surmounted by sandstone of lightish colour, which, though it weathers to a brownish red colour, cuts, as a freestone, to a whitish tint. The thick-bedded sandstone with pink grains is surmounted at Balligill by dark-grey ichthyolite-flags charged with *Coccosteus, Osteolepis, Dipterus, Diplopterus, Cheiracanthus,* and certain plants. These beds graduate into limestones which have been extensively worked for use, one of the beds being 3 feet thick and followed by thin flaggy courses. On the whole, however, the lower part of the series in its western extension is already seen to be parting with the character which is dominant in Caithness, and is becoming more a sandstone formation, with included limestone.

The bosses of the granite on the shore near Port Skerry have evidently penetrated, when in a molten state, into the gneiss, whilst both these rocks have afforded the fragments composing the lower breccia and conglomerate. In truth, all this part of the coast having been subjected to violent breaks and faults, the hard crystalline granite, porphyry, altered rocks, and gneiss have in such movements been necessarily protruded here and there through the softer sandstone and flagstone. But that all such crystalline rocks were previously solidified, is proved by the fact that their materials forming the breccia and conglomerate here constitute the highly irregular base of the Old Red series. This angular breccia, evidently formed under tumultuous conditions, alternates, however, with fine-grained, hard, siliceous sandstones, into which it passes up, and finally into building-stone.

Fig. 12.—*Section along the Burn of Isauld, near Reay, showing a passage from the Lower to the Middle Member of the Old Red Series.*

* Granite. *a.* Granitic red conglomerate. *b.* Hard grey siliceous sandstone. *c.* Calcareous dark-coloured flagstone, with geodes of limestone. *d.* Soft light-coloured sandstone. *e.* Ordinary dark-grey Caithness flags, with ichthyolites.

In proof of the very local character of the coarse breccia, the observer has only to move a few miles eastward to Reay, and, in descending the banks of the little Burn of Isauld to the sea-shore, he will find that there the fundamental granite has undergone no dislocation, and that the conglomerate, or base of the Old Red lying on it, consists of pebbles which have evidently been rounded by the long-continued action of waves upon a shore, while the lower part of the flagstones, presenting the same predominance of sandstone as above remarked, and containing some limestone, passes in even and unbroken beds under the great mass of the Caithness series with its fossil fishes. The order is represented in the section, fig. 12.

Fossil Remains in the Caithness Flags.—I have little new matter to add in respect of the animal remains of this deposit of flagstones. The genera and species of the fishes are already well known; but I may state that a specimen of a *Coccosteus* lately discovered by Mr. Peach exhibits a vertebral column more completely ossified than that of any hitherto-discovered specimen. Again, it is to be noted, that the *Asterolepis*, found by Hugh Miller in the lowest beds of the Orkney succession, has been detected, both by Mr. John Miller and Mr. Peach, in the highest beds of Caithness. Of the prevalent genera, *Osteolepis*, *Dipterus*, *Cheiracanthus*, *Diplopterus* and *Coccosteus*, the fish usually lowest in the strata of Caithness is the *Osteolepis*; it may also be stated that a *Pterichthys* has lately been found in the Orkney Islands.

I must not omit to speak of the only shell, or rather shell-like Crustacean, yet discovered in these flags, and which occurs abundantly at Kirkwall in the Orkneys, and has also been found near Lerwick in the Shetland Isles. This is a small *Estheria*, a Phyllopodous bivalved Crustacean, such as are found in African and South American rivers. It is about half-an-inch long, and marked by sharp concentric lines of growth, and has the general aspect of a small *Astarte*, or *Venus*. It occurs in certain localities in such numbers as to form layers an inch or two thick, entirely made up of the thin carapaces. It has been described for me by Mr. T. Rupert Jones, and is named by him *Estheria Murchisoniana*.

Description of a small Bivalve Crustacean from Caithness.

Estheria Murchisoniana, spec. nov. Woodcut, fig. 14, *c*, *d* (p. 408).

The carapace-valves of a small bivalve crustacean, occurring plentifully on some of the surface-planes of the Caithness Flagstones, near Wick, and also in the Orkney and Shetland Isles, have been noticed by Hugh Miller and others *. Their close resemblance to the shells of small bivalve molluscs formerly led to their being taken for the shells of *Venus*, *Cyclas*, &c.; but their supposed relation to molluscs having been doubted, some specimens from near Thurso, collected by Mr. Peach, were given to me by Mr. Woodward; and a far larger number, and better preserved, from Kirkwall and Murkle Bay, were confided to me for examination by Sir R. Murchison last winter.

In their substance, consistence, configuration, and size, these little valves offer

* See Dr. Malcolmson's Memoir, *antea*, p. 351; Miller's 'Old Red Sandstone,' 4th edit. p. 132, pl. 5. fig. 7; and Sir Roderick Murchison's remarks above; and at pp. 411, 413.

direct analogies to the bivalved carapaces of certain recent Phyllopodous Crustaceans inhabiting the rivers and lagoons * of hot countries, and often much resembling the shells of *Nucula*, *Cyrena*, &c.

Great numbers of the valves are spread over large surfaces of the flagstone, sometimes scattered sparsely, sometimes congregated in groups, forming films between the layers of the fissile stone. Sir Roderick remarks (above, p. 404) that their distribution appears to be very local;—I have not learnt how thick the band, or bands, of the flagstone may be that they affect. The valves are usually single; pairs, with their hinge-lines in juxtaposition, are rare. The specimens which I have are in dark-grey, tough, fine-grained, sandy flagstone, slightly micaceous, somewhat varying in tint and hardness. They usually appear to have a superficial smoothness or even gloss, and often a light-brown tint, with some degree of translucency. But the substance of the valve flakes off readily, leaving a film on each of the two surface-planes in a split stone; and it is comparatively seldom that a valve shows its real exterior; for, though the surface may sometimes come away from the stone in splitting, and leave a clean cast, yet an outer flake of the valve seems nearly always to have fallen away with the shock of the blow; and the sandy nature of the matrix is too coarse to retain traces of any very fine microscopic sculpturing in the cast or mould of the surface.

In the Kirkwall specimen the valves are pyritized; but those from Caithness retain their brown horny tissue, although the outermost surface is seldom preserved, and only in little patches on some valves. From this circumstance it is very difficult to form a correct diagnosis of the species; for the superficial ornamentation yields important specific characters in this genus, and in this case it cannot be well studied.

A careful examination of the materials at my command enables me to describe the carapace as follows:—

Valves variable in shape from a subquadrate to an oblong form,—some being about $\frac{1}{6}$th inch long and $\frac{1}{8}$th inch high, and others being as high as long. The hinge-line is straight; the generality of the valves have the anterior and posterior edges forming sharp angles with the dorsal line and passing vertically with a slightly convex outline to the boldly-rounded ventral border. In this case the umbo is distinct, almost in the middle of the back line, and bordered by a triangular depressed ear on either side; something like a miniature *Cucullæa auriculifera*.

There are also valves which are longer and narrower, with the ends rather more convex, and the ventral border somewhat straight. Here the umbo is less protuberant and nearer to one end (the anterior?).

In each of these forms the surface is wrinkled, by about 18 to 20 concentric, rounded, closely-set ridges, uniform with the outline of the ventral border and extremities of the valve. The ridges are coarsest near the umbo, their starting point, and they become finer as they approach the edges of the valve.

Under the microscope, the patches of the outer surface, here and there retained, are seen to be of a dark-brown opake substance, exhibiting on and between the ridges a finely granular appearance, which is probably the real condition of the surface; or it may be due to an accidental modification of an originally minute reticulate ornament.

As it is possible that the difference in shape between the many subquadrate and the few oblong valves may be due to pressure, to a condition of growth, or perhaps to difference of sex, it would be too hazardous even to distinguish them by name as varietal forms †. Indeed, circumstances have so modified the great majority of the valves, that the whole outline of a valve can very rarely be definitely traced even among a hundred individuals; for the edges either

* The *Estheria minuta* of the Trias is the subject of a note in the Quart. Journ. Geol. Soc. vol. xii. p. 376; and I have there referred to the Caithness form. The information, accompanying a recent specimen, which led me to term *Estheria* a "marine" crustacean (*op. cit.* p. 377), is, I find, probably erroneous, or at least requires to be substantiated.

† In one or two instances I was almost misled by apparently elongate valves, which were, in truth, two valves pressed accidentally one on another "conformably," but still one extending a little beyond the other.

overlap, or are squeezed out of proportion, or are broken away, or, lastly, remain buried a little way in the matrix.

I had hoped to have completed an account of all the known fossil Estheria-like Crustaceans before offering any remarks on these Caithness specimens. But, for the present, I can only observe, that the form most like to them that I know of is the so-called *Posidonomya Keuperiana* of Germany (as far as some few casts which I possess can show). Still there is a slight difference as to shape (I have as yet no means of comparing the valve itself of the German triassic form referred to), and I prefer to regard them as distinct; and I cannot do better than dedicate this fossil *Estheria* of Scotland to one who has devoted so much labour and time to the elucidation of its geological relations.

Mr. Salter has lately shown me some specimens from Russia which appear to be identical with *Estheria Murchisoniana* (but in a matrix of light-grey clay very different from the Caithness flagstone). These are labelled "*Asmusia membranacea*, R. Pacht;" but I do not know whether they have been described. It does not appear to me at present that there are any grounds for separating these fossils from the recent genus *Estheria*. The term *membranacea*, having been already given to one of the Wealden *Estheriæ* (*Cyclas membranacea*, Sow.), is preoccupied.—July, 1859. T. R. J.

The following passages respecting the fossil plants of this deposit are extracted from the last edition of 'Siluria':—

Plants of the Caithness Flags.—The most marked addition to the fossil contents of the Old Red Sandstone consists of various fossil plants. Even as late as the year 1854 I could allude to only one unquestionable land-plant as having been found in this formation by Hugh Miller, and described by him as a part of a Coniferous tree. The same author had afterwards brought to the notice of the British Association for the Advancement of Science, in 1855, several of these fossil plants, which have since been published in his posthumous work the 'Testimony of the Rocks.' Most of these have been there referred to tree-ferns and illustrated in that work by woodcuts.

Living at Wick, in the central portion of the Caithness flags, Mr. C. Peach has laboured incessantly in that locality to discover organic remains, and has succeeded in disentangling certain fossil vegetables (as well as many ichthyolites) from these hard rocks. The plants are all clearly of terrestrial origin, and are of the same species as those which have been found in the Orkneys by Dr. Hamilton, and at Thurso by Mr. John Miller and Mr. Robert Dick, who have collected many excellent specimens near that town, some of which are figured below.

[These fossil remains of vegetables have been figured and described at large in the Quart. Journ. Geol. Soc. (vol. xiv. p. 72, pl. 5) by Mr. Salter, who has also supplied the following succinct notes on the plants.]

The most striking, perhaps, of these fossil plants are very large, long, flattened bodies, which, from their state of preservation, were clearly woody stems (fig. 13. 6). They were 4 or 5 inches broad, and as many feet in length, fluted longitudinally, and possessing a central pith. Though these plants have often been converted into thin plates of crystalline coaly matter, their forms remain distinct, and, under the careful microscopic scrutiny of Professor Quekett, they have exhibited a true coniferous structure. In the arrangement and number of the disks upon the fibres, they approach near to the Araucarian group. In general appearance, and even in the mode of preservation, they strikingly resemble certain fossil forms from the Upper Devonian rocks of Saalfeld in Germany, collected by Dr. Richter,—such, for instance, as the *Aporoxylon* of Professor Unger; but this differs in being of simple structure, and possessing no pores or disks on the woody fibre.

These fluted fragments are without doubt stems; and similar but more slender specimens found with them are as clearly the branches, which have borne whorls of smaller twigs, like their living representatives. Again, large branching woody roots, fig. 13. 5, but destitute of superficial markings, appear to have belonged to the same trees, and are often several feet long. With these occur very many specimens of a *Lepidodendron*, 4, with short scaly leaves—*L. nothum*, Unger?

or a species very like it; a *Lycopodites*, 3, with long prostrate stems and secund or one-sided foliage, like that of the common *Lycopodium clavatum*. This last may of course be of quite a different natural order, and even coniferous; but its general resemblance alone is implied in the name.

Linear branched or dichotomous fragments, some of them smooth (1, 2) and destitute of all markings, have also been found, whilst others, like them, are covered with small tubercles in quincunx order, and are probably the roots of the *Lepidodendron*, 4.

The probability of the smooth forms, 1, being also roots, is very strong. Similar bodies occur in beds of the Upper Devonian series in N. Devon and the South of Ireland, and in such a position with regard to the fluted stems of *Knorria*, with which they are associated, as to lead to the belief that they are the rootlets of that plant. The larger ones have even markings similar to those of the main stem.

This probability is strengthened by finding similar linear specimens with them, which bear tubercles or excrescences at their tips and along their sides very like those on the roots of Leguminous plants and many of the Conifers. The latter is the more probable analogy.

Hugh Miller has, indeed, figured a similar fossil as probably belonging to an ancient marine plant resembling the *Zostera*, and has reasonably speculated on the existence of wide fields of such vegetation on the muddy shores of the Old Red period. But our more perfect specimens justify the belief above-stated; and as yet there is no evidence of any marine plant in the Caithness schists. The vegetable remains have evidently been swept from adjacent lands into the sea inhabited by the fishes above-mentioned.

Fig. 13.—*Fossil Plant-remains from the Old Red Sandstone of Caithness.*

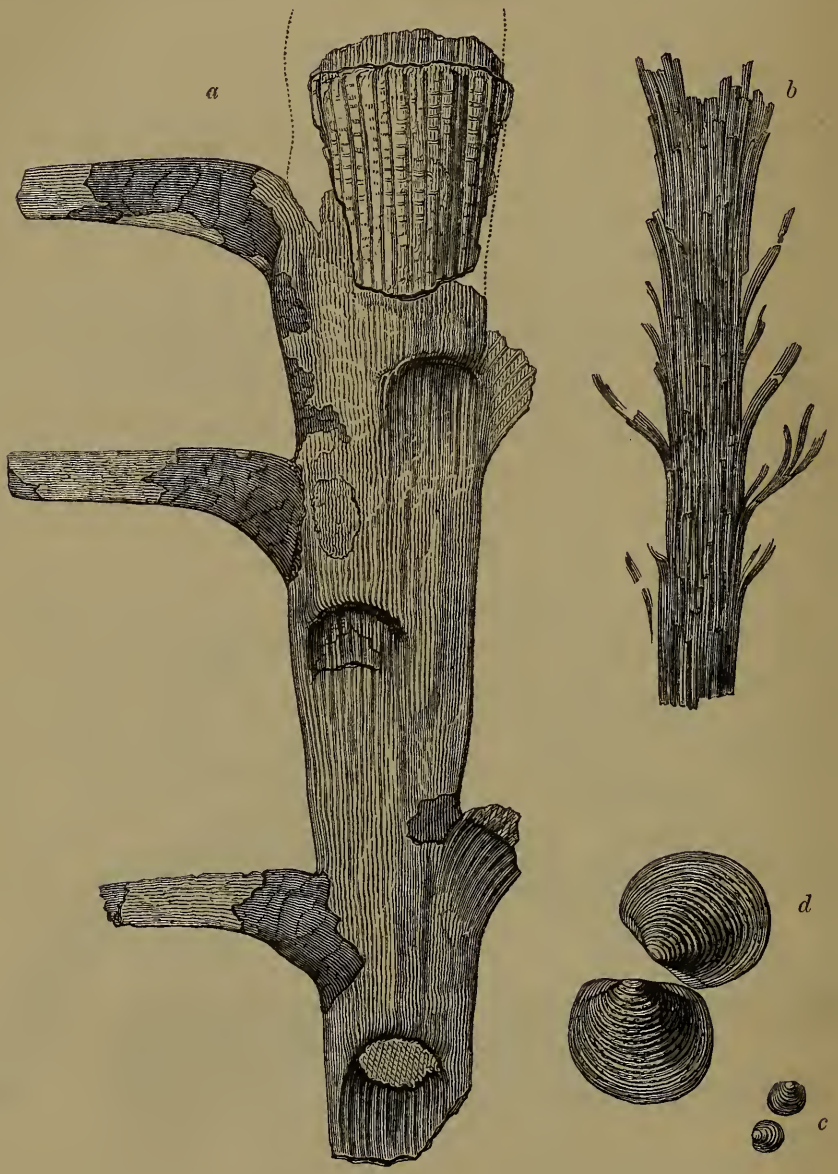
(From 'Siluria,' new edit. p. 290.)

(Very common) 1. Branched rootlets of some Lycopodiaceous? plant. 2. Dichotomous roots of *Lepidodendron*?, upon a surface marked with double annelide-burrows. 3. *Lycopodites Milleri*, Salter; one-third nat. size. 4. *Lepidodendron nothum*, Unger?, one-third nat. size. 5. Flattened root, and 6. Fluted stem, of Coniferous tree, about one-sixth nat. size.

A fossil plant very recently found differs from any one hitherto published, and is so peculiar, from the rectangular setting-on of its lateral branches, that it is here figured; and, though its genus is

doubtful, it has at my request been named (after its discoverer) *Caulopteris*? *Peachii*. See fig. 14. The stem is wider beneath each branch, and striated for a short distance.

Fig. 14.—*Fossil Plants and Crustacean from the Old Red Sandstone.*



a. Stem of Tree-fern (*Caulopteris*? *Peachii*, Salter); ⅓rd nat. size. Thurso.
b. Young shoot of a Coniferous? plant, showing leaves; half nat. size. Duncansby Head.
c, *d*. *Estheria Murchisoniana*, Jones; nat. size and magnified. Murkle Bay, Caithness (collected by Mr. R. Dick).

The flora, then, so far as can be made out, consisted of Coniferous

trees, some of considerable size*, and, according to their minute structure, of the Araucarian type; *Lepidodendron* also is rather abundant, and a *Lycopodites* occurs. It is but a scanty assemblage, after all, as to species, but may be compared with that flora recently detected by Prof. Dawson in the Devonian beds of Nova Scotia, where *Coniferæ* of a somewhat different type, and *Lepidodendra*, are the chief forms described †. On the whole, it is analogous to that of the Carboniferous formation, though distinct as to species. There were large Coniferous trees—with whorls of branches, and with a structure like that of the Norfolk-pine; also *Lepidodendron*, *Lycopodites*, and Ferns. That these grew near the coast and were entombed in the shallows of a muddy shore, seems proved by their good preservation and from the coarse nature of the matrix, which is, moreover, indented by the burrows of sea-worms, like those made upon the shores in our own day.

As we advance still higher in the series, or into the strata which overlie the Caithness flags, other fossil plants of large size begin to appear; and several of these have been discovered in the Orkneys and Shetlands by Mr. Tufnell and Dr. Hamilton, and belonging either to *Columnaria* or to some allied genus, make an approach to forms usually considered as characteristic of the Carboniferous era (p. 413).

Upper Old Red of Caithness.—In various parts of the north coast of Caithness the series of dark-coloured flagstones, nearly all more or less bituminous, is seen to graduate upwards into light-coloured sandstone, in parts reddish, but usually of yellowish colours. At Reay, indeed, such sandstones are developed so very low in the series (see Section, fig. 12, p. 404) as to be interlaced with some of the lowest beds of flagstone. Here and there, as between the town of Thurso and Holborn Head, a band of this character is intercalated higher up among the flagstones, and the beds, being thicker and softer than the associated flagstones, are used for building.

Fig. 15.—*Section showing the relations of the Caithness Flags to the Upper Old Red Sandstone in the neighbourhood of Dunnet Head.*

In the bold promontory, however, of Dunnet Head, the observer ascends from the flagstones as exhibited on the coast from Barrogill Castle to the fishing-villages of Ham and Brough, as represented in the Section, fig. 15, where, after several undulations and breaks, those dark bituminous and ichthyolitic beds are carried under the

* A large carbonized stem similar to those first mentioned (p. 406) has recently been discovered by Mr. Peach. It measured several feet in length by sixteen inches in breadth, thus proving that these Old Red plants attained the dimensions of large fir-trees.

† Proceed. Geol. Soc. January 5, 1859.

headland of a yellowish sandstone, occasionally weathering red. When viewed from Castle Hill, *i. e.* on its western side, this headland presents a reddish exterior; and it is partially so externally on the north and eastern faces; but when closely examined on the last-mentioned flank, the rock, which rises in terrace over terrace to the Lighthouse, 340 feet above the sea, is on the whole of a yellowish colour. The lowest beds visible near Brough are of reddish-brown colour, with blotches of light-coloured, and occasionally greenish, crystalline spots; the next ledge is a thick-bedded, finely-laminated, slightly micaceous freestone, weathering white, but partially of yellowish-brown tints. The higher courses consist of strong bands of sandstone and coarse grit of whitish, yellowish, and dull brown-red colours, with rarely occurring small pebbles of quartz,—some of the beds, particularly those on the summit of the headland, containing elongated argillaceous blotches or concretions of dark-red and greenish colours*.

These overlying sandstones are much more largely developed in the Orkney Islands than in the county of Caithness.

Old Red of the Orkney Islands.—These islands, as far as I have seen them, exhibit essentially the same geological character as the rocks of Caithness. Possessing as extensive a development of the ichthyolitic flagstones as Caithness itself, they exhibit a still greater thickness of the superior and light-coloured sandstone, or third division of the Old Red, than is anywhere to be seen in the main land of Scotland.

In the principal island of Pomona, we observed, at two localities, that the flagstones were underlaid by conglomerate and sandstone. Remarking that the beautiful Cathedral of Kirkwall was built of a red freestone which has retained the sharpness of its architectural ornaments for centuries, and, seeing that the Caithness flags, on which the town stands, dipped away slightly to the north, we passed over eastwards to the Bay of Meal, to look out for a red sandstone of which we had heard, and there found red and mottled sandstone arching over and rising out from beneath the flagstones. As we also detected the same mottled red sandstone on the S.E. side of Scapa Bay, where it is inclined at an angle of 65° to pass under the flagstone series, and trends to the westward, we had no doubt that this rock, which crosses the promontory to the Bay of Meal, was the same which had been worked for the construction of the cathedral. This feature seems to have escaped the notice of former explorers; and the fact proves that the ichthyolite-flagstones have the same base, not only of conglomerate, but also of red sandstone, in Orkney as in Caithness.

The chief masses of rock which succeed, are largely cut into in

* Though we sought in vain for any organic remains in these yellowish sandstones, Mr. Peach has since detected plants in sandstones at Duncansby Head, and also at Friswick, on the east coast. At the former place a conglomerate charged with pebbles of greenstone occurs; and in one of the thin beds of sandstone, a stem, apparently with leaves, was found, which is represented in fig. 14 (*b*).

the east hill above Kirkwall, and may be best paralleled with some of the rocks near Wick,—being hard, tough, and thick-bedded enough to be used as rude building-stones. They are also bituminous, and are here and there copiously charged with fish-remains; for in them we found *Coccosteus* and many remains of other ichthyolites.

These stony bands are followed, on the north side of the harbour, by thin flagstones, which, in addition to numerous ichthyolites, are laden with the little Crustacean *Estheria* (p. 404), which, wherever it occurs, is equally characteristic as the fishes, being abundant in some spots of Caithness, particularly near Thurso. With the exception of the partial axis of the lower sandstone of Kirkwall, and a lower conglomerate near Stromness, which is formed out of and rests upon granite, just like the examples on the coast-confines of Caithness and Sutherland, the whole of Pomona seems to be so occupied by the ichthyolitic flagstones, that if the Roman leader who named the island had been a naturalist, he might aptly have named it *Piscina*. Occupying all the interior hills as well as the plains on which the famous Stennis Stones stand, these flagstones are admirably exposed on the shore to the N.E. of Stromness, where dipping away from low bosses of granite and the conglomerate formed out of that rock, they form broad undulations, all along the northern shore, the cliffs between Breakness and Holbrow rising here and there to 150 feet or more above the sea.

It is unnecessary here to recapitulate the numerous ichthyolites which Pomona has yielded. We ourselves met with *Osteolepis*, *Coccosteus*, *Asterolepis*, *Dipterus*, *Diplopterus*, *Diplacanthus*, and many fossil plants. The works of Agassiz and Miller teem with data on this head,—Dr. Traill having supplied the former with many of the new specimens*.

In availing myself of the opportunity to visit the northernmost of the Orkney Islands (Ronaldsha) and the Shetland Isles, in the steamer of the Commissioners of the Northern Lighthouses, I was prevented from extending the observations made in the environs of Kirkwall and Stromness, into the adjacent island of Hoy. Of the general order, however, in that island, there can be no doubt; for, whether it be viewed from Dunnet Head, from the sea, or when sailing under its cliffs on the east, west, and north sides, or by walking along the opposite shores of Pomona, near Stromness, or again when standing, as we did, upon the low, small island of Gremsa, the succession is unmistakeably exhibited. Observed in all these ways, the flagstone-rocks of Caithness, occupying low cliffs and terraces, are seen clearly to pass under and to be superposed by the reddish and yellowish sandstone of the Hill of Hoy, which, where it extends to the vertical maritime precipice on its north-eastern face, with its outlier the Old Man, has been ascertained to have a height of 1130 feet. I much regret not having explored this headland,

* The finest collection in Pomona is in the possession of the Rev. C. Clouston. (See Dr. Malcolmson's memoir, p. 348.) The traveller will find, in the excellent and comfortable inn at Stromness, kept by Capt. Flett, a little museum containing many of these ichthyolites.

which well merits a careful examination. I am not aware that any geologists, except Hugh Miller and Dr. Malcolmson, ever visited it*; and they were not able to detect any fossils in the sandstone of such great thickness, all of which, however, they clearly recognized to be (as indeed I had ascertained it to be many years before) younger than the Caithness flags. Though much affected by vertical fissures, the beds of the overlying sandstone are clearly seen to be very gently inclined to the N. and N.N.E., in conformity with the underlying flagstones.

The mere fact that sandstones of such great thickness overlie and graduate downwards into the Caithness flags, has necessarily had great influence in predisposing me to believe that other sandstones, apparently occupying a like position on the south side of the Moray Firth, are also of the Old Red age. This point will be considered in the following memoir.

On disembarking on North Ronaldsha, the northernmost of the Orkney Islands, we found that the flagstone series was still persistent; and, though we detected no fishes in our cursory examination, we found there a few fossil plants similar to those of Caithness.

Judging from the uniform character of the cliffs which we constantly passed near to in other islands, such as Rowsha, Stronsha, Shapinsha, and Eda, I infer that the chief stony masses of all the islands, seldom rising to more than 200 feet, are referable to the Caithness flags, though it is probable that the fine building-stones of the two last-mentioned islands, which are of light-yellow and whitish colours, belong to the upper member of the series, or that which we examined in Dunnet Head.

On the whole, however, and judging from the hard and siliceous nature of the beds at North Ronaldsha, it would appear that the ichthyolitic and bituminous schists and flagstones, which have their maximum development in Caithness, Pomona, and the Southern Orkneys, part with many of their peculiar characters in their range northwards, just as I have already shown that they change in their eastward range into the north-eastern parts of Sutherland, between Reay and Sutherland. In the sequel, this change of petrographical composition will be still more dwelt upon when we follow these beds southwards into Ross-shire, and thence to the south side of the Moray Firth.

Old Red Sandstone of the Shetland Islands.—In the rapid glance I obtained of this extensive group of islands, I could attempt little more than the simple determination that the sandstones, long ago described by Dr. Hibbert as "transition" and "secondary," were prolongations of the Old Red series of the Orkney Islands†.

At Somburgh Head, the most southerly point of the main island jutting out between the indentations called the East and West Voe, is a noble vertical cliff 300 feet high, on the summit of which the

* It appears, from the preceding memoir, that Dr. Malcolmson examined this bold headland in some detail, but met with no fossils there (p. 351).

† They are now so marked in the Geological Maps of Knipe and Nicol.

lighthouse stands. The chief mass of the rock is a finely micaceous light-grey sandstone, in parts reddish, and weathering brownish-red with a slight dip to the E.S.E., or away from the older rocks, which range from the Fitful Head to the N.N.E.

In the more flag-like and thinner beds of this sandstone, and at the very summit of the rock on which the lighthouse stands, Mr. Peach and myself found numerous fragments of plants. Hence we had no hesitation in considering this sandstone, and a fine conglomerate which it contains, to be of the same age as the rock which we had left at North Ronaldsha in the Orkneys, and to be really a part of the Old Red series.

As we steamed forwards to Lerwick, the cliffs of Lumboga Head, Troswick Ness, No Ness, and the Isle of Mousa seemed to consist of thin-bedded rocks pertaining to the same series; and in passing close along the western shore of the Isle of Bressay, we saw that the strata were thrown over on a dome-shaped rock of red colour. This mass and the overlying grey beds near the centre of the island are evidently carried under the beds of sandstone constituting the promontory on which the Lighthouse is placed. These beds, of light-grey colour and much charged with mica, dip to the E.N.E. at about 30°, and in lithological character are not unlike some of those of Somburgh Head. They contain casts of the trunks and branches of trees, the stems of which are fluted and void of joints.

At Lerwick, which is just opposite Bressay, we visited the quarries on the shore to the south of the town, which have afforded a considerable number of those plants, including those brought to me some years ago by my friend the late Right Hon. H. Tufnell*. The sandstone in which these plants are imbedded is of a brownish-red colour, whilst under Queen Charlotte's Fort, at the north end of Lerwick, the rock passes down into a thick-bedded mass with a few rounded pebbles, almost a conglomerate.

Although the ichthyolites of the Caithness flags have not yet been discovered in the Shetland Isles, the existence of strata of this age in the environs of Lerwick is placed beyond a doubt, by the discovery, in flaggy beds, of the same little Crustacean (the *Estheria*) which occurs at Thurso and Kirkwall.

Again, judging from the superposition of the sandstones of the Bressay lighthouse to a great inferior mass of rocks, there can be little doubt that these, as well as the plant-beds of Lerwick, pertain to the younger portion of the Old Red Sandstone †.

On inspecting several specimens which a quarryman had collected, one of which was nearly 5 feet long and 6 inches broad, it was clear that none of these plants possessed joints, as already noticed by Dr. Hooker‡. They were simply long fluted stems without any

* Quart. Journ. Geol. Soc. vol. ix. p. 49.

† In his new map, Professor Nicol has accurately distinguished the Old Red of the east coast of Scotland from the much older Cambrian rocks of the west coast; and in his Geological Map of the British Isles, Mr. Knipe had also properly extended the Old Red along this portion of the Shetland Isles.

‡ Quart. Journ. Geol. Soc. vol. ix. p. 49.

transverse division whatever, and could not, therefore, I presume, be referred to *Calamites*. They are unlike any Carboniferous plant ever discovered, and on that account also are, in all probability, to be grouped with the plant-bearing Upper Devonian beds of Saalfeld in Germany and other places.

*General View of the Old Red or Devonian Rocks**.—The method of grouping the Old Red Sandstone deposits of Caithness, the Orkneys, and the north-eastern counties of Scotland, as above described, is in accordance with the tripartite division of their geological equivalents, the Devonian rocks of Devonshire, Belgium, and Germany. Referring to the Table of Classification published in 'Siluria,' I would here also indicate how unanswerably the zoological contents of the Devonian rocks of Russia (*i. e.* of deposits lying clearly between the uppermost Silurian and the lowest Carboniferous stratum) sustain my belief that the Old Red of Scotland and Herefordshire is the equivalent of this intermediate group on the continent of Europe. Proofs of the intermingling, in the same beds, of the seashells of the Devonshire limestones, with species of fishes identical with those of the Scottish Old Red Sandstone (the identity being determined by Agassiz), were first given in the work 'Russia and the Ural Mountains,' and were, I then presumed (1845), sufficient to demonstrate the truth of my inferences. Perceiving, however, that scepticism still partially prevailed on this subject, and that, Russia being far off, the statement of my associates and self had not made such an impression as the facts called for, I wrote to my friend Colonel Helmersen, who has given much attention to the stratigraphical arrangement and zoological contents of the Devonian rocks of Russia, and, referring to the recent admirable publication of Pander, I requested him to inform me distinctly to what extent the ichthyolites of the Old Red Sandstone of Scotland were commingled in Russia with Devonian mollusks. His answer was clear and decisive, in assuring me that there are many places, besides those seen by my associates and self, where the marine mollusca of Devon and the Boulonnais are mixed up with Scottish species of Old Red ichthyolites.

The lowest known Devonian strata in the north of Livonia, and thence ranging into the Government of St. Petersburg, repose transgressively upon various members of the Silurian rocks. Thus, in the Isle of Oesel, as described in a memoir recently read before this Society†, the uppermost Silurian rocks of the Isle of Oesel are shown, from the shells they contain, to be perfect representatives of the Ludlow rocks of England. With these are associated portions of many new genera, in addition to the *Onchus* and *Thelodus* of those British Upper Ludlow rocks; and with them two new species of the *Cephalaspis* have also been shown to occur. Thus far the physical and zoological relations of the uppermost Silurian rocks of Russia are in accordance with those of the typical region of England. Whilst, however, the latter affords evidence of a complete and unbroken transition upwards into the overlying Old Red, the same

* See Tables at pp. 437–439. † Quart. Journ. Geol. Soc. vol. xiv. p. 48.

intermediate zone is wanting in Russia*, the lowest Devonian or Old Red stage being there absent.

In Russia the lowest Devonian stage consists of the sandstones and shales which contain the fossil fishes of the north of Livonia, and those of the environs of Dorpat and of Tellin on the Lake of Rustuck. The fishes of this zone are those which Asmus first described (including the great *Asterolepis*), and of which Pander has in the last year given a more detailed and extensive account, and with that genus we now also have there the well-known *Coccosteus* of the north of Scotland. These beds graduate upwards into dolomitic limestone and shale richly charged with Mollusca, which in Germany, France, and elsewhere are recognized as middle and upper Devonian types,—the most frequent being *Spirifer Archiaci*, *Sp. Anosoffi*, *Productus productoides*, *Terebratula Livonica*, and abundance of Encrinites, &c. Now, in the very same beds with these sea-shells, corals, and crinoids, we find the *Holoptychius Nobilissimus*, and many of those fishes which are characteristic of the central and upper portions of the Old Red Sandstone of Perthshire in Scotland; in short, fragments of such ichthyolites are often found in hand-specimens, intimately mixed up with the above-mentioned mollusks, and in localities widely separated from each other, in several Governments of Russia. By this intermixture, it is demonstrated, that the theory, partially indulged in, of the freshwater origin of the Old Red ichthyolites is quite untenable. The uppermost Devonian stage of Russia, whether composed of red or whitish soft sandstone, or of greenish marls, as on the Priutchka River in the Valdai Hills, where I have examined it, and where it underlies conformably everything carboniferous, is laden with remains of ichthyolites, three of which are also identical in species with the fossil fishes of the Old Red Sandstone of Scotland and different from any known in the Carboniferous series. These are the *Holoptychius Nobilissimus*, *Glyptosteus favosus*, and *Diplopterus macrocephalus*. Judging, therefore, from the organic remains alone, we see that the lowest British zone, or that with *Cephalaspis* and *Pteraspis*, *Pterygotus*, and *Parka decipiens*, is wanting in Russia. There, the inferior strata, or those containing *Coccosteus*, *Dipterus*, *Asterolepis*, &c., represent the Caithness or central zone of our country; whilst the superior Russian members are equivalents of the higher portions of the Old Red Sandstone of Scotland and the limestones and slates of Devonshire, since they unite the fishes of the former country with the sea-shells of the latter. A reference to the work, 'Russia and the Ural Mountains,' and to the 'Fishes of the Old Red Sandstone' of Agassiz, suffices indeed to establish the correctness of this view, now that we know what is the real stratigraphical base of the British Old Red Sandstone; for all the species mentioned in other publications as common to Britain and Russia (to the number of twenty-one) occur in the middle and upper strata only of the Old Red of our own country†.

* See 'Siluria,' new edition, p. 384.

† Tables accompanying the following memoir will show the comparison

The proofs of the synchronism of these distant deposits through the identification of their included ichthyolites, and the intermixture of the sea-shells of Devon with the fishes of the Old Red of Scotland, entitled me to say of my associates and self, that "if our researches in Russia had led to no other result, they would, we conceive, have well repaid our labours*."

Nowhere in Russia is there, I repeat, a geological and zoological transition from the Upper Silurian, like that which is seen in Shropshire and Herefordshire. In this last-mentioned British tract the observer traces a gradual passage upwards from the bone-bed of the Upper Ludlow Rock with remains of a few peculiar fishes into the Tilestones in which the genus *Cephalaspis* first appears, but still associated with some Silurian mollusks, whilst in the beds immediately overlying we have the *Cephalaspis Lyellii*. The total absence of that genus, or, indeed, of any of the types of the Lower Old Red of England, Forfar, and Perthshire, in the lowest Devonian of Russia, when coupled with the fact that the Russian ichthyolites belong to the middle and upper zone of the series, is in perfect harmony with the above-noticed physical break.

Newer Red Sandstone of the West Coast of Ross-shire.—Professor Nicol having recently described† a Newer Red Sandstone as covering unconformably the higher inclined beds of the older conglomerates and sandstones on the shores of Loch Greinord, as first observed by Macculloch, let me add the notice of this deposit, which I take from my note-book of 1827. On reaching the shore of Loch Greinord, Professor Sedgwick and myself found three small headlands to be composed of a newer red sandstone separated from each other by sandy bays. The lowest beds are conglomerates and marls, which near Udrigill Head repose upon highly inclined (in parts nearly vertical) beds of older conglomerates and sandstone that form points protruding through the newer strata.

The lower conglomerate (now ascertained to be of Cambrian age) is overlaid by micaceous red sandstone and marls with greenish-white blotches, often of circular shape, whitish gritty beds of incoherent red sand, and other beds of conglomerate, the uppermost bed visible near the burying-ground being red sandstone with calcareous veins and red marl. Looking at the incoherent character of the sands and marls, which there occupy the sea-board for about two miles, and knowing that the conglomerate and grits with Lias fossils, as I had observed in the previous year, occur at no great distance on this coast of Ross-shire, and also that these Lias beds are underlaid by a red sandstone, my associate and self, without publishing the details of our note-book, gave it as our belief that the soft sandstone and marl of Loch Greinord belonged to the New Red Sandstone.

But this our old inference is scarcely to be relied on; for at that

between the British and Russian deposits, and the genera of ichthyolites which characterize each division of the Old Red or Devonian rocks.

* See 'Russia in Europe,' &c., vol. i. p. 63.

† Quart. Journ. Geol. Soc. vol. xiv. p. 167.

day we were necessarily unacquainted with the numerous ages during which the red sandstones and conglomerates of Scotland had been accumulated. It has, in fact, been ascertained that the conglomerate and sandstone of the West Highlands, which then passed for Old Red Sandstone, is of Cambrian age, and hence it follows that the red deposits lying unconformably upon those rocks may belong to the Old Red as well as to any other overlying deposit.

Of the Scottish red sandstones and conglomerates we may now indeed reckon the following:—

1st. Cambrian, or that of the N.W. Highlands.

2nd. Great Lower Silurian conglomerates of Ayr and Wigton.

3rd. Old Red base, underlying the Caithness Flags.

4th. Old Red summit, overlying the Caithness Flags.

5th. Carboniferous varieties.

6th. Permian conglomerates and sandstones of the S.W. of Scotland—Dumfries, Ayrshire, and the Isle of Arran.

7th. Red and green marls and sandstones, supposed to be of Triassic age, as seen in small detached portions.

Lias and Oolitic Deposits.—These Secondary deposits, which, as is well known, occupy large breadths in the Hebrides and are more sparingly distributed along the N.E. of Scotland, are now much better known than when I first endeavoured to make English geologists conversant with them by comparing them with their best types in England *. They will be again alluded to in the following memoir.

The late Hugh Miller has since expatiated on their fossil contents and peculiarities on both shores of the Highlands; whilst the breccias of the Oolite of Brora near Helmsdale have afforded to his scrutiny a multitude of beautiful fossil plants, which complete the resemblance of these northern deposits to their equivalents on the east coast of Yorkshire. The intercalation of freshwater beds in these Oolites, of which I only obtained a glimpse thirty years ago, has since been matured on the east coast by the late Mr. Robertson †, as well as by the late Edward Forbes on the Isle of Skye ‡. As respects the Liassic and Oolitic succession of the Hebrides, Mr. Geikie § has recently much improved our knowledge of the relations and boundaries of all the rocks in parts of the highly diversified Isle of Skye.

These subjects are indeed beyond the gist of the present memoir, and they are here merely touched upon in order to unite in one general view the whole of the ascending order of all the stratified deposits which really exist in the Northern Highlands.

Lastly, above all these lie those grand superficial accumulations of drift and huge erratic blocks, which, whether studied with reference to their glacial origin, or as connected with raised beaches of different levels, open out some of the most exciting subjects with which the geologist can grapple; they are, however, unconnected with my present object.

* See Trans. Geol. Soc. Lond. 2nd ser. vol. ii. p. 293.

† Proceed. Geol. Soc. vol. iv. p. 173; and Quart. Journ. Geol. Soc. vol. iii. p. 113.

‡ See Quart. Journ. Geol. Soc. vol. vii. p. 104. § Ibid. vol. xiv. p. 1.

EXPLANATION OF PLATE XIII.

Fossils from the Limestone of Durness.

Fig. 1 *a*. *Maclurea Peachii*, Salter. Under or flat face, with the operculum added (1 *b*) to show its normal position.
Fig. 2. —— Upper or convex side of another specimen.
Fig. 3. —— Restored outline, seen from the front, with the operculum in position.
Fig. 4. —— Operculum, upper view.
Fig. 5. —— Operculum, viewed from within.
Fig. 6. Operculum of *M. Logani*, Salter. For comparison. In these figures, *a* is the straight lower edge; *b*, the umbo; *c*, the inner lower angle; *d*, the upper angle.
Figs. 7, 8. *Murchisonia gracilis*, Hall; var. *gracillima*.
Figs. 9, 10. *M. angulocincta*.
Fig. 11. *M. bellicincta*, Hall?
Fig. 12. *Ophileta compacta*, Salter. *a*, the lower face; *c*, the upper concave face; *b*, the convex dome-like cast of the upper surface.
Fig. 13 *a*. *Pleurotomaria Thule*, Salter. A portion of the surface, 13 *b*, magnified twice.
Fig. 14. *Orthis striatula*, Emmons. *a*, dorsal valve; *b*, a portion of the same magnified.
Fig. 15. —— Dorsal valve.
Fig. 16. —— Ventral or convex valve.
Figs. 17–21. *Piloceras invaginatum*, Salter. Fig. 17 is a specimen of a nearly perfect mouth, drawn behind the abraded specimen, fig. 18, which shows the concentric septa on the rough section, and is obscurely annulated on the outside; fig. 19 is the conical curved tip; fig. 20 shows a section of the cap-like septa in a fractured specimen; fig. 21 gives a transverse view of another specimen, showing three concentric septa.
Fig. 22. *Orthoceras vertebrale*, Hall? or young of *O. bilineatum*, Hall? Compressed and bent specimen.
Fig. 23. *O. vertebrale*, Hall?
Fig. 24 *a*. *Orthoceras mendax*, Salter. Broken, and showing the subcompressed siphuncular tube; 24 *b*, transverse view of concave septum with siphuncle, from near the smaller end.
Fig. 25. *Orthoceras undulostriatum*, Hall. Interior view with angularly bent septum.
Fig. 26. —— Front (or ventral?) view of another specimen.
Fig. 27. *Oncoceras*? undescribed species. A very doubtful specimen.

Fossils from the Quartz-rock and Shale.

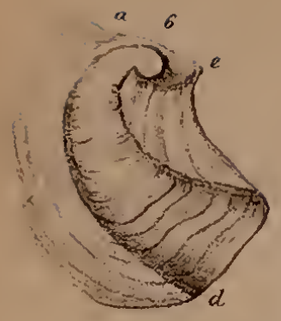
Fig. 28. Annelide-tube (*Helminthites*), or trail.
Fig. 29. Double burrows (*Arenicolites*) in quartz-rock.
Fig. 30. —— Side view of another specimen, showing the contents of the burrows, roughly striated in a vertical direction.
Fig. 31. *Serpulites*? *M'Cullochii*, Murchison. In a mass of sandstone. These thick, short, free annelide-tubes are very common in the quartzose sandstones of Durness.

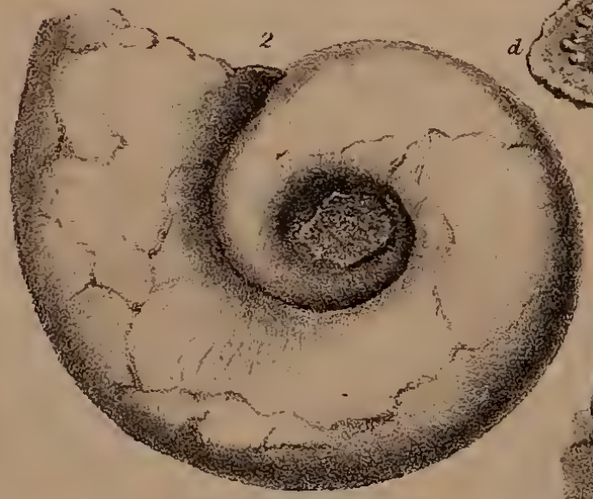
Tuffen West lith. ad nat.

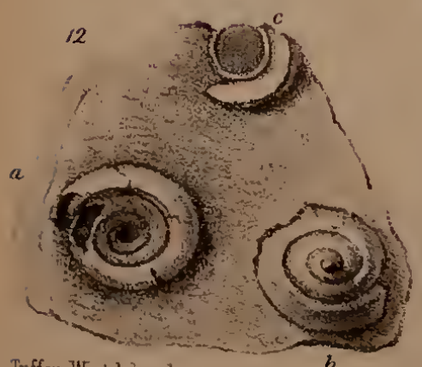
LOWER SILURIAN

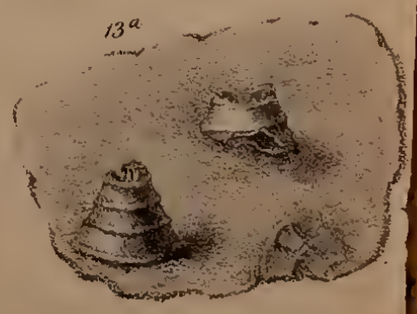
W. West

SILS FROM DURNESS



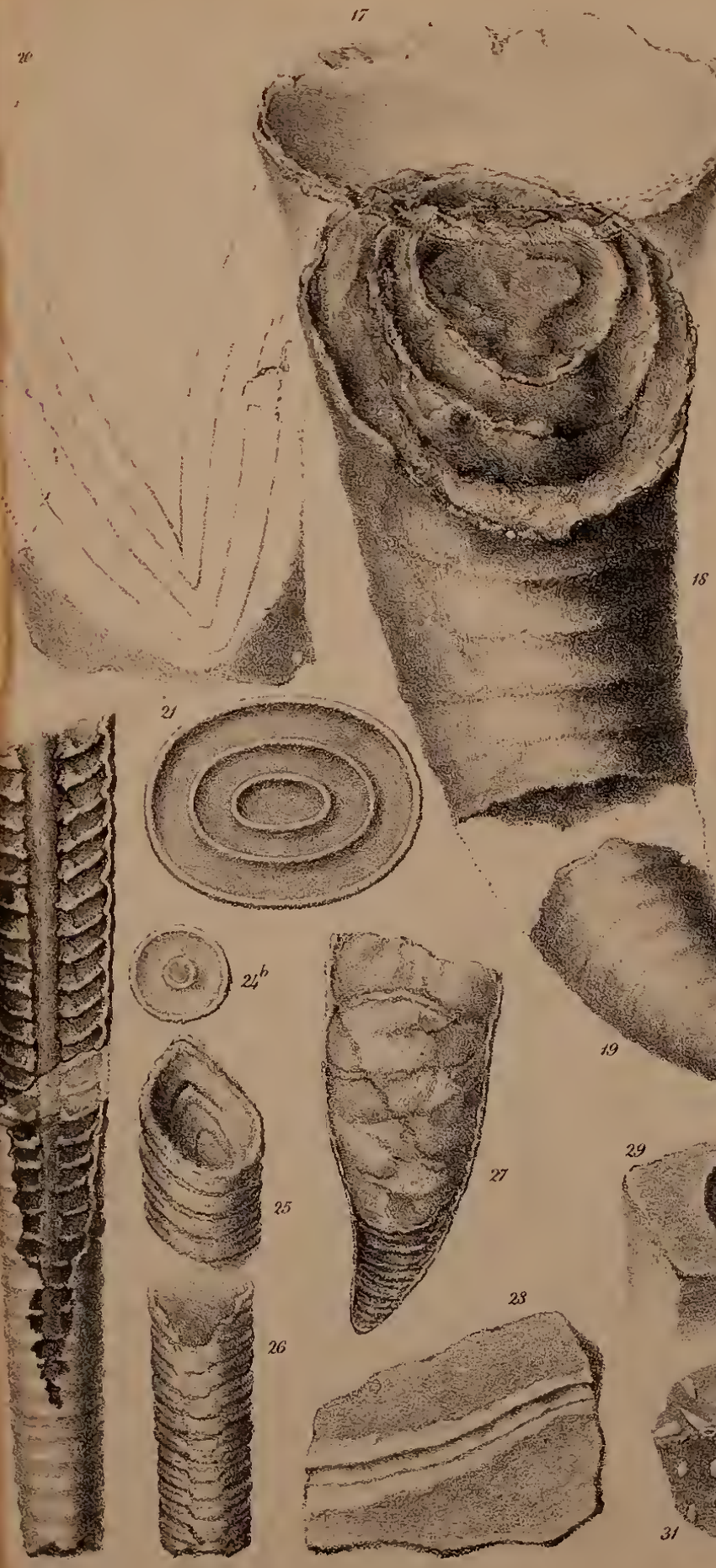






Tuffen West lith ad nat.

LOWER SILURIAN FO



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SSILS FROM DURNESS

NOTICE.

PLATE XII., consisting of a Geological Map of the Highlands, will appear in a future number of the Journal, as mentioned in the foot-note at p. 359.